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SOUTHERN
Instruments

SOUTHERN INSTRUMENTS LIMITED

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HANDBOOK

for

F-M EQUIPMENT

series M.1800

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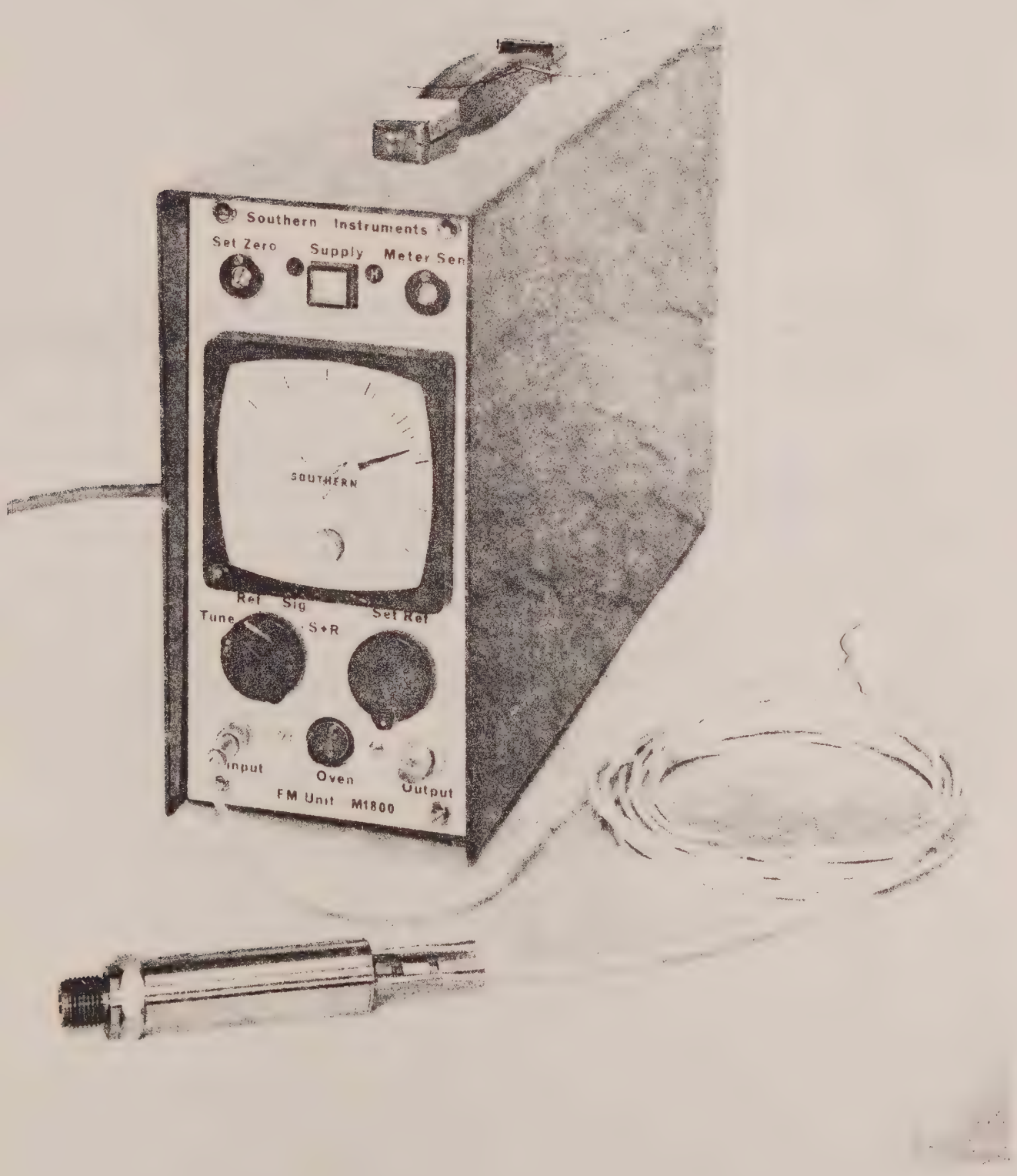


FIG. 1 M1800-H UNIT (CONNECTED TO TYPE T500 TRANSDUCER).

1 INTRODUCTION

The S.I. F-M system provides a means of converting physical quantities (such as pressure, vibration, position etc.) into proportional electrical signals, which can be displayed, recorded and analysed in a very convenient manner. The input may be static or transient.

The basis of the system is the conversion of the physical quantity to be measured into a proportional change in the frequency of a 2 Mc/s carrier wave. The physical input is applied to a transducer, where for example it may be arranged to vary an internal inductor or capacitor, which in turn controls the frequency of an oscillator circuit. The resulting changes in oscillator frequency are applied to a frequency discriminator circuit, whose output is a direct voltage proportional to the input frequency change. The output voltage, which is thus directly proportional to the original physical input quantity, may be displayed on an oscilloscope: its mean value is shown on a 4 $1/_2$ inch Cirscale meter built into the instrument.

Other facilities available include outputs for driving galvanometer recorders; alarm level circuits; outputs to drive digital counters, or for recording the signal on magnetic tape. A wide range of transducers is available, and this range is being continually extended.

2 SPECIFICATION

2.1 EQUIPMENT SCHEDULE

M1800-H high linearity f-m units: contains the following sub-units:

M1800 f-m unit (chassis assembly)
M1810 high linearity discriminator assembly.
M1815 or M1816 mixer board
M1831 power unit (for 200-250 V a.c. 50-60 c/s)

M1800-W wide band f-m unit: contains the following sub-units:

M1800 f-m unit (chassis assembly)
M1820 wide band discriminator assembly
M1816 mixer board
M1831 power unit (for 200-250 V a.c. 50-60 c/s)

Other associated units which can be suppliedseparately are as follows:

M1822 Inductive Transducer Oscillator
M1828 Capacitive Transducer Oscillator
M1840 Galvanometer drive board

M1848
M1849 Alarm level boards
M1850

M1851 bench mounting case for panels totalling 4 inches width
M1852 bench mounting case for panels totalling 8 inches width
M1853 bench mounting case for panels totalling 12 inches width
M1854 bench mounting case for panels totalling 16 inches width

M1855 Nest unit, for mounting in 14 inch minirak, for panels totalling 12 inches wide.
M1856 Nest unit, for mounting in 19 inch rack, for panels totalling 16 inches wide.

2.2 ELECTRICAL SPECIFICATION

(a) Input Signal:

Nominal frequency 2 Mc/s
Tuning range of M1800: 1·9-2·1 Mc/s
Input signals will normally be derived either from a type M1822 or M1828 transducer oscillator unit, or from a series 500 transducer containing a built-in oscillator.

(b) Output:

	High-linearity version M1800-H	Wide-band version M1800-W
Full-scale output:	Nominal ± 3 V for ± 20 kc/s input frequency change (fullscale on meter is obtained for 40 kc/s ± 1% input frequency change).	Nominal ± 3V for ± 20 kc/s input frequency change
Linearity: (best straight line through origin)	± 0·2%	± 1%
Frequency response: (-3 dB)	0-10 kc/s	0-70 kc/s
Rise Time:	35 usec	5 usec
Overshoot:	less than 1%	less than 1%
Phase slope (group delay)	60 usec	5·5 usec
Drift: (0-50°C ambient temperature and ± 10% supply variation)	less than ± 0·5%	less than ± 1%
Noise level:	more than 52 dB below maximum signal.	more than 54 dB below maximum signal.

Output impedance:	less than 200 ohms	less than 200 ohms
Load resistance:	not less than 6 kohm	not less than 6 kohm

(c) Frequency modulated output:

(for use with counters and tape systems)

Amplitude:	greater than 1 V p-p	No output available
Frequency:	30 kc/s (zero input) 70 kc/s (full scale)	
Drift:	less than ± 100 c/s (for ambient temperature range 0-50°C).	
Output impedance:	1 kohm	

(d) Power Supply:

24 V d.c. ± 10% at 1A maximum or 200-250 V a.c. 50-60 c/s at 30 VA.

2.3 MECHANICAL SPECIFICATION

	Basic Unit	In Bench Case
Height:	8 inches (203 mm)	8•5 inches (216 mm)
Width:	4 inches (102 mm)	4•1 inches (104 mm)
Depth:	10•8 inches (274 mm)	14•5 inches (368 mm)*
Weight:	5•7 lb (2•6 kg)	11 lb (5 kg)*

* includes mains power unit.

3 PRINCIPLES OF OPERATION

3.1 GENERAL PROPERTIES OF THE F-M SYSTEM

Equipments in the Southern Instruments M1800 series, with their associated transducers, operate on the frequency-modulated carrier system: that is, the transducer is designed to convert changes in the appropriate physical input quantity into proportional changes in the frequency of a 2 Mc/s carrier wave. This conversion is made at or near the transducer, and the carrier wave is then passed down a cable to the M1800 series F-M unit. Here the signal is amplified, and then applied to a frequency discriminator circuit, which converts frequency change to proportional changes in d.c. output voltage.

Use of this type of system has a number of advantages:

(a) Once the conversion of frequency has been made, the signal can be transmitted long distances without error, because any variations in signal amplitude introduced by cable losses have no effect on the frequency.

(b) For the same reason, the system is basically insensitive to most forms of electrical interference.

(c) Use of a high carrier frequency (2 Mc/s) allows the transmission of a wide range of signal frequencies (e.g. 0-70 kc/s in the wide band version).

(d) A convenient form of digital readout for steady signals can be obtained by displaying the signal frequency on a digital counter.

3.2 TRANSDUCER DESIGN

The development of transducers for f-m systems is simple in principle, though very careful design is necessary to acheive

satisfactory performance in practice. In a typical pressure transducer, for example, application of pressure to a diaphragm can be arranged to alter the capacitance between the diaphragm and some fixed electrode, or to alter the inductance of a pick-off coil mounted near the diaphragm. Use of a high carrier frequency (2 Mc/s) allows the use of physically small coils and capacitors; the relatively small frequency change used (2% change in frequency = full scale) ensures that the frequency change is a linear function of the input quantity over this range. For static measurements, an oscillator circuit of very good frequency stability is required, because drift in the oscillator frequency cannot be distinguished from a change in transducer input. Earlier transducers were designed to be connected to an external oscillator unit through a length of cable limited to some 10 feet. This arrangement had the advantage that the oscillator was reasonably remote from the transducer environment; however, the transducer cable capacitance appeared directly across the tuned circuit, and tended to contribute appreciable drift. For this reason, some of the more recent transducers have been designed with the oscillator circuit built into the transducer body, thus eliminating this type of cable effect.

3.3 CALIBRATION OF TRANSDUCERS

The sensitivity of the transducer/oscillator combination, expressed in terms of frequency change out for full scale input to the transducer, depends on a number of factors, not all of which are under the designer's control. Also, the sensitivity of the read-out equipment (expressed in terms of full scale voltage output for full scale frequency change) was in earlier equipments a somewhat variable quantity. It was therefore invariably necessary to carry out an overall calibration of transducer and read-out equipment prior to taking measurements. The introduction of the M1800-H equipment and the T500 series of transducers with built-in oscillators has improved this situation, though overall calibration is still good practice, of course. The M1800-H (high linearity) unit requires a frequency change of 40 kc/s to produce full scale deflection on the output meter: the T500 transducers are calibrated in terms of the input required to produce a 40 kc/s change in carrier frequency. Overall calibration is then simply a check that operating conditions are similar to calibration conditions.

Overall calibration for accurate work is still essential, (a) when using the M1800-H with earlier types of instructive and capacitive transducers, in conjunction with the M1822 or M1828 transducer oscillator; and (b) when using the M1800-W wide band for unit with any type of transducer. (The sensitivity of the M1800 discriminator in the M1800-W depends to some extent on the carrier frequency; this feature is common to all frequency discriminators of this class).

Some of the earlier designs of inductive transducer produce a frequency change of only 20 kc/s, when used with the M1822 oscillator. Details will be found in the handbook for the M1822.

3.4 THE F-M DISCRIMINATOR UNIT

The M1800 unit is required to accept the signal generated in the transducer oscillator, and convert changes in frequency in this signal (40 kc/s change in 2 Mc/s, for full scale input) into a proportional output voltage. Basic design requirements are to achieve linearity, stability of zero, a low output noise level, and an adequate frequency and transient response. These requirements are to some extent contradictory: accordingly two alternative versions of this unit have been designed, with the following characteristics - (reference to the schematic diagram M1800/1 may be helpful):

(a) The high linearity version (M1800-H) has a linearity of 0·2% and a zero stability of 0·5%. This unit operates by translating the input frequency changes from 2 Mc/s to a centre frequency of 50 kc/s, thus raising the percentage change in frequency for full scale from ± 1% to ± 40%. This allows the use of a constant-area-pulse type frequency discriminator, which automatically gives good zero stability and linearity. Furthermore, the sensitivity is exactly the same for all input frequencies, and M1800-H units are set up to produce full scale deflection on the meter for 40 kc/s ± 1% input frequency change. However, the use of a lower carrier frequency restricts to 0-10 kc/s the range of signal frequencies which can be handled; this, plus the noise introduced in the frequency changing process, limits the noise level to some 300 times (52 dB) below maximum output signal.

(b) The wide-band version (M1800-W) handles signal frequencies in the range 0-70 kc/s. The discriminator circuit operates directly at 2 Mc/s; this allows the use of a simpler output filter, and gives some improvement in output noise level, which is now some 500 times below maximum output signal.

The high-linearity and wide-band versions of the M1800 unit differ basically only in the type of discriminator unit fitted. Information on how these units are installed will be found in section 7.2 below, and circuit details in section 8. (Note that earlier types of M1800 chassis require wiring modifications before the wide band discriminator can be used satisfactorily).

3.5 FREQUENCY AND TRANSIENT RESPONSE

Any system using a modulated carrier can handle only a limited

range of signal frequencies, extending up to less than 20% of the carrier frequency: this is because it otherwise becomes impossible to separate signal and carrier frequency components in the discriminator output. Apart from any limitations imposed by the transducer characteristics, the frequency response of the whole system is largely controlled by the output filter used. In all Southern Instruments equipment, the output filter response is of the Gaussion form; this form of characteristic gives the best transient response, because all input frequency components are subject to the same time delay, and thus e.g square waves are reproduced without overshoot. Details of the amplitude, transient and phase responses of the systems are given in paragraph 6.7.

4 INSTALLATION OF M.1800 F.M. UNIT

4.1 MAINS SUPPLY

Mains supply connection to the instrument is made via a miniature 3-way plug and socket mounted on the Power Unit module at the rear of the instrument. The mains voltage selector panel near the plug should be set to suit the local supply voltage, before connecting the instrument.

4.2 24V D.C. SUPPLY OPERATION

This requires the removal of the Power Unit (M.1831-2-3) from the rear of the M.1800 unit: unscrew from the Power Unit the four 4 B.A. fixing bolts -two on each side, nearest the front of the instrument. Remove the Power Supply Unit, and unplug the flying lead. The 24V supply may now be connected to the red and black terminals provided, taking care to observe polarity. The lever on switch S2 should be turned anti-clockwise (to obscure PL1).

Note:

(i) The 24V supply must be isolated from earth.

(ii) Up to three M.1800 Units can be operated from one battery.

(iii) Current drain is 1A maximum. To conserve battery power, the oven heater may be switched off by turning S2 clockwise. Current drain then falls to about 0•2A, but drift in equipment may be greater. The pilot and oven lights will not operate.

4.3 MISCELLANEOUS

(a) Connect display equipment (e.g Cathode-ray oscillograph) to OUTPUT socket.

(b) For M.1800-H only:

Either remove the jack plug from SK3 at the back of the instrument, or check that tip and ring of the plug are linked inside the plug, and that the plug is fully home.

(The plug breaks the signal line when inserted, unless the link has been fitted inside the plug).

5 INITIAL SETTING UP

5.1 FRONT PANEL CONTROLS

The following controls are mounted on the front panel of the M1800 unit (see figure 1).

1. SUPPLY switch: this push button switch controls the mains (or battery) supply to the instrument. The action is press on, press off.

2. FUNCTION switch: this has four positions, marked as follows:

   TUNE: Used for setting up the frequency of certain transducer oscillators, and for checking that a signal is present at the INPUT terminal.

   REF: In this position, a variable d.c. voltage (adjustable by the SET REF control) appears at the output terminal, and is displayed on the meter.

   SIG: This is the position normally used in making measurements. The signal output voltage appears at the OUTPUT terminal, and the mean output voltage is shown on the meter.

   S + R: (SIG + REF): In this position, the signal and REF voltages are summed algebraically. This facility is used when measuring instantaneous values (see below).

3. SET REF: This control is a 5-turn potentiometer which controls the reference voltage.

4. SET ZERO: A 10-turn pre-set potentiometer which controls the electrical zero of the signal.

5. METER SENS: A variable resistor, which increases the meter sensitivity if required. (Fully anticlockwise gives a standard setting which is f.s.d. for 40 kc/s frequency change, on the high linearity version of the M1800.

5.2 ALTERNATIVE VERSIONS

The M1800 f.m. unit is available in two forms: (1) the high linearity version (M1800-H), identified by a letter H visible in one of the small circular windows adjacent to the on-off button; and (2) the wide-band version (M1800-W) identified by a letter W in this position.

These units may be used either with transducers in the T500 series, which contain an internal oscillator, or with older types of transducer which require a separate transducer oscillator: type M1822 for inductive transducers, and type M1828 for capacitive transducers.

The setting-up procedure is similar in all cases, but to avoid confusion separate sections below are devoted to each combination.

5.3 INITIAL ADJUSTMENTS

Switch on M1800, by depressing the red button marked SUPPLY on the front panel. The pilot light and oven light will come on. Allow $1/_2$ hour for warming up; the oven light will occasionally go off, showing that the oven thermostat is working.

Turn METER SENS (top right panel) fully anticlockwise. Turn S1 to position marked TUNE. Any recording or display equipment (e.g oscilloscope, galvanometer recorder) connected to M1800 output may conveniently be zeroed at this stage: the trace should be set in the exact centre of the required range. (The M1800 output is connected to earth via 100 ohms in this position). With no connection to the INPUT socket, the meter should read between 56 and 64 on the black scale.

5.4 SETTING ZERO: (A) HIGH-LINEARITY F.M. AND T.500 SERIES TRANSDUCER

Turn the SET ZERO control (top left of panel, 10-turn pre-set control) fully clockwise. Connect the transducer to the INPUT socket of the M1800 unit via the cable provided. Turn SET ZERO anticlockwise until the meter reading just peaks at a value of above 70.

Switch S1 on M1800 to SIG, with no input to the transducer, and use the SET ZERO control to zero the meter needle. (Note that the meter needle should turn in the same direction as the SET ZERO control; if the reverse is true, see paragraph 5.8. on page 14. Set to 0 on the black scale for all transducers except differential or bidirectional types, which obviously require the centre zero (red) scale.

This completes the setting-up procedure.

5.5 SETTING ZERO (B) HIGH LINEARITY F.M. AND M1822/M1828 TRANSDUCER OSCILLATOR

Connect the transducer oscillator output cable to the M1800 INPUT socket. Turn the SET ZERO control on M1800 3 1/2 turns back from the fully clockwise position. With the transducer connected to the M1822/M1828 input lead, but with no input applied to the transducer, set the OSC TUNING switch on M1822/M1828 to position 0, and then turn it clockwise until the meter reading on M1800 just peaks (at over 70). If two nearly equal peaks are obtained, always use the lower number switch position.

Switch S1 on M1800 to SIG, and use the SET ZERO control to zero the meter needle as described below, (note that the meter needle should turn in the same direction as the SET ZERO control: if the reverse is true, see paragraph 5.8 page 14).

When using the M1822 oscillator, set the meter needle to 0 on the black scale for all transducers except differential or bidirectional types, which obviously require the centre zero (red) scale.

When using the M1828 oscillator, set the meter needle to 100 on the black scale, for all transducers except differential or bidirectional types, which obviously required the centre zero (red) scale.

This completes the setting-up procedure.

Note 1. As explained in the M1828 handbook, capacitive transducers used with M1828 give a reverse sense output; i.e. an increase in pressure makes the output voltage from M1800 more negative. If this is inconvenient, the sense of the output can usually be reversed by turning the SET ZERO anticlockwise until the meter needle goes off the l.h. end of the scale, and then returns; the needle now moves in the opposite sense to the SET ZERO. Now set the needle to 0 on the black scale.

Note 2. It is possible to set up M1822/M1828 when this unit is remote from M1800: see handbook for these units.

5.6 SETTING ZERO (C) WIDE BAND F.M. AND T500 SERIES TRANSDUCERS

With S1 on M1800 set to TUNE, connect the cable from the transducer to the INPUT socket, and note that the meter reading increases, to above 70 on black scale.

Switch to SIG. With no input applied to the transducer, use the SET ZERO control to zero the meter needle. Set to 0 on the black scale for all transducers except differential or bidirectional types, which obviously

require the centre zero (red) scale.

This completes the setting-up procedure.

5.7 SETTING ZERO (D) WIDE BAND F.M. AND M1822/M1828 TRANSDUCER OSCILLATOR

Turn the SET ZERO control on M1800 3 1/2 turns back from the fully clockwise position. Connect the transducer to the M1822/M1828 input lead; ensure that there is no input to the transducer.

With S1 of M1800 set to TUNE, connect the M1822/M1828 Transducer Oscillator output cable to the INPUT socket of M1300, and note that the meter reading increases (to about 70).

Switch S1 of M1800 to SIG position. Turn the OSC TUNING switch on M1822/M1828 clockwise from position 0 until the meter needle comes on to the scale. Now use the SET ZERO control to zero the meter needle, as follows:

(a) When using the M1822 oscillator: set the meter needle to 0 on the black scale for all transducers except differential or bidirectional types, which obviously require the centre zero (red) scale.

(b) When using the M1828 oscillator: set the meter needle to 100 on the black scale, for all transducers except differential or bidirectional types, which obviously require the centre zero (red) scale.

This completes the setting-up procedure.

Note 1. As explained in the M1828 handbook, capacitive transducers used with M1828 give a reverse sense output, i.e. an increase in pressure makes the output from M1800 more negative.

5.8 ALTERING SENSE OF OUTPUT VOLTAGE

As mentioned above, for some settings of the SET ZERO control of the high linearity f.m. unit, the meter needle moves in the reverse sense to the control. In this condition, the polarity of the output voltage is reversed; to correct, turn SET ZERO clockwise until the needle goes off the 1 h. end of the scale, and then returns; the sense is now correct.

6 OPERATION OF M1800

6.1 GENERAL

The initial adjustment procedure given in sections 5.3 to 5.7 ensures that (1) the transducer oscillator is producing an adequate output, and (2) the zero of the M1800 and any associate display equipment (CRO, U-V recorder etc.) has been set correctly. The equipment is now ready for use.

6.2 'SIG' POSITION

With the function switch S1 in the SIG position, the meter deflection and the voltage appearing at the output sockets are proportional to the input to the transducer. The various quantities are related as follows:

Input to transducer: (Input to differential transducer:	0% -100%	50% 0%	100% +100%
Meter reading (black scale):	0	50	100
Output voltage at SK10 (nominal): ± 10%	-3V	0V	+3V
Frequency at SK3: (M1800-H only)	30 kc/s	50 kc/s	70 kc/s

6.3 CALIBRATION OF SYSTEM

It is desirable where possible to calibrate the system overall; this checks the transducer sensitivity and eliminates non-linearity errors. A series of known inputs is applied to the transducer, and the coresponding meter readings noted; a calibration curve may then be plotted.

Note that the meter scale can be expanded so that the meter gives full deflection on less than 100% input. This should of course be done before calibrating the system. The METER SENS control is used for this (see paragraph 6.6 page 17), and should then be locked, using the grub screw.

6.4 'REF' POSITION

With S1 in the REF position, the meter reading and output voltage can be set to a steady value anywhere in the normal range of the instrument, by adjusting the SET REF control. This facility is useful when placing calibration lines on records, and when setting the gain of display devices (e.g CRO's, galvanometers) so that the M1800 output gives full deflection.

6.5 MEASUREMENT OF INSTANTANEOUS VALUE OF ANY POINT ON OUTPUT WAVEFORM

Switch to S + R; view the output waveform on a CRO, and use the SET REF control to bring the selected point on the output waveform to the centre (zero volts) line of the display. The meter now reads the instantaneous value of this point on the waveform, in terms of the calibration (paragraph 6.3).

It may also be convenient to switch to the S + R position to avoid large meter deflections on slow signals. In this case, SET REF must be used to set the meter to 0 on the red scale (50 on black scale), otherwise the output waveform will be shifted from the centre of the display, and may distort on peaks.

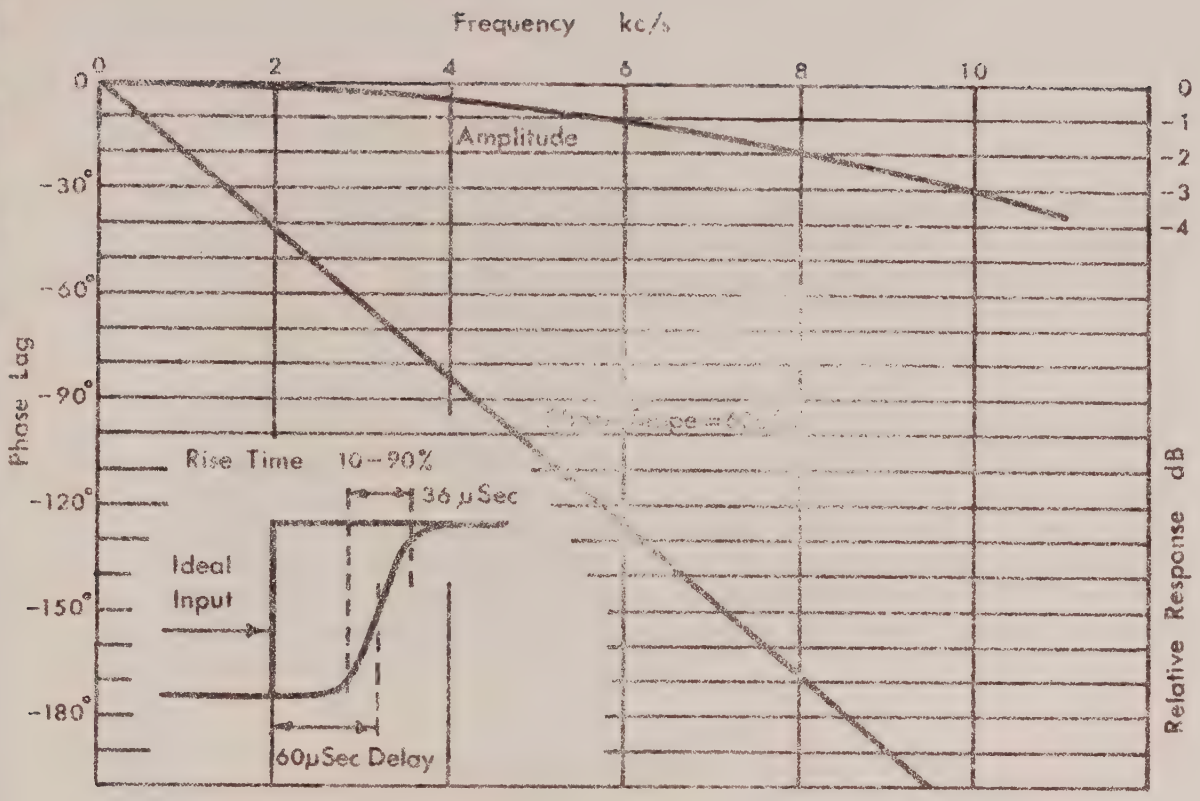


Fig 2a Response of M1800-H High-Linearity F.M. Equipment

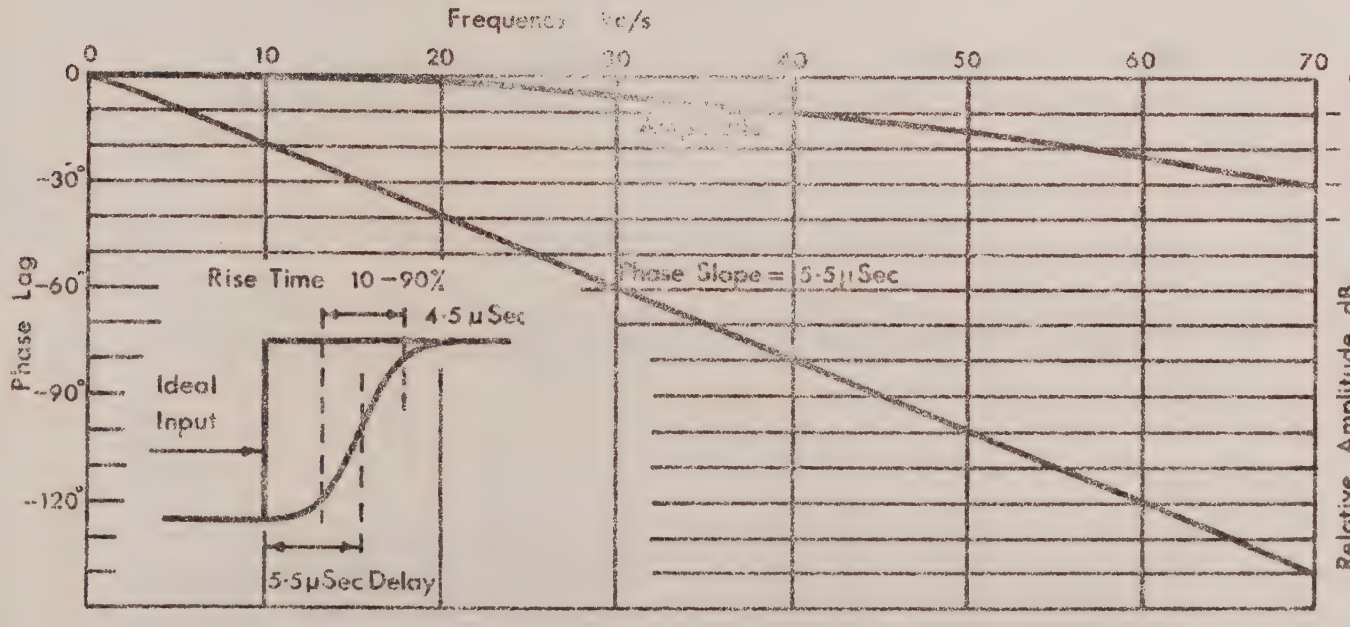


Fig 2b Response of M1800-W Wide-Band F.M. Equipment

6.6 EXPANSION OF METER SCALE

The METER SENS control can be used to expand the meter scale so that full scale on the transducer equals full scale on the meter. Expansion is about the centre of the scale, and by a factor of up to 4x. The voltage output from M1800 is not affected.

Use of the control is obviously straightforward when using differential transducers and the red meter scale. The following technique is recommended for undirectional transducers: set meter zero as described in paragraph 5.3. to 5.7 pages 12 to 14. Apply maximum input to transducer, and note reading on black scale (say x units). Remove input to transducer; use SET ZERO to move pointer to value $1/_2$ x on left-hand-side of RED scale; then turn SET SENS clockwise until meter again reads 0 on black scale. Meter will now read full scale for full input.

6.7 TRANSIENT RESPONSE AND PHASE SHIFT

All practical amplifier systems (i.e. those having finite bandwidth) introduce a time delay into the signal path. In systems having good transient response (i.e no overshoot) this time delay is the same for all frequency components, which implies that the phase shift increases linearity with frequency. Diagrams showing phase shift against frequency, time delay, and rise time for the two versions of the M1800 system are given in figure 2.

Note that these only refer to the effect of the M1800 unit; in many cases the limited frequency response of the transducer will be more significant.

6.8 AUXILIARY OUTPUT AND CONNECTIONS

The various plugs and sockets located at the rear of the M1800 unit provide the following facilities: (refer to M1800B/1 circuit).

6.8.1

Voltage output appears between pins 5 and 6 (earth) on PL2; this point is connected to the OUTPUT socket on the front panel. It may also be used to drive sensitive galvanometers, through a suitable matching network (see drawing M1300/341 for an easy method of calculating the values required). The total current drawn should not

exceed ± 0·5 mA (i.e the minimum value of load resistance is 6 kΩ).

6.8.2

Current output. A voltage proportional to the current through the meter appears between pin 10 and 6 (earth). This may be used to drive an external 0·5-0-0·5 mA meter; in a permanent installation, the 270 Ω resistor R16 across pins 10 and 6 may be disconnected. (It is desirable to keep the total resistance between pins 10 and 6 at 270 Ω, to avoid altering the M1800 meter sensitivity).

This connection may also be used for the connection of galvanometers; the disadvantage is that transient signals are likely to be distorted by voltages generated by the meter movement, so the output should be used with the function switch in the "S + R" position only, when the meter is out of circuit.

6.8.3

Frequency output (SK3). On the high linearity f.m. unit (M1800-H) only, the 30-70 kc/s output from the mixer is taken to the tip contact of the 3 way jack socket SK3, and the discriminator input to the ring contact. Thus a digital frequency meter or other monitoring device may be connected, without disturbing the circuit action, by using a jack plug with a link between tip and ring. Alternatively, if it is required to apply a signal direct to the discriminator (e.g for test purposes), connection should be made to the ring contact only. (The earth connection is also used in all cases, of course).

6.8.4

Remote zero set. The electrical zero of the instrument is controlled by the voltage on the slider of the SET ZERO control. This voltage is brought out to PL2 at pin 1, and is returned to the discriminator circuit through a 120 kΩ resistor R15 mounted between pins 1 and 9 of PL2. To obtain remote control of zero, an auxilary 10 turn 20 kΩ potentiometer should be connected between pin 1 and pin 6 (earth), and the SET ZERO control should be turned fully anticlockwise and locked. The slider of the auxiliary potentiometer is then connected to pin 9, and this gives remote control of zero. (Warning: Any hum or other voltages picked up on pin 9 will appear as an output signal, so suitable screened leads should be used).

This facility is used when the M1800 is connected to the M1336 or M1837 switching panels.

6.8.5

Galvo drive amplifier M1840 (board No. M4083). This circuit is available on a separate printed circuit board, which plugs into SK7 in the M1800 chassis. The amplifier provides up to ± 50 mA into a 35 Ω load, as the M1800 output voltage varies by ± 3 V. The gain may be reduced to a value 50 times below this by means of a gain control, accessible through hole C in the M1800 screening cover. Remote gain control is also possible. Full details are given in the M1840 handbook.

The current output from the M4083 board appears on SK3; connections are as shown on the M1800B/1 diagram.

6.8.6

Alarm circuits (M1848, M1849, M1850). Single and dual alarm circuits are available as separate printed circuit boards, which plug into SK8 in the M1800 chassis. Associated relays plug into SK11 and SK12 inside the rear panel of M1800. Connections from the relay contacts are brought out to PL2, at the rear of the M1800 unit, as shown on circuit diagram M1800B/1.

These alarm circuits provide a relay contact closure when the M1800 output exceeds or falls below a preset level. (The level controls are accessible through holes D and E in the M1800 screening cover). Full details are given in the appropriate handbook.

Note: Under some conditions, the connection of 230 V mains circuits to the relays via PL2 can result in an increased hum level on the signal output, arising from pick-up onto pins 9 and 1 (see paragraph 6.8.3 on page 18). This can be reduced by connecting a lower value resistor (say 10 KΩ between pins 1 and 9).

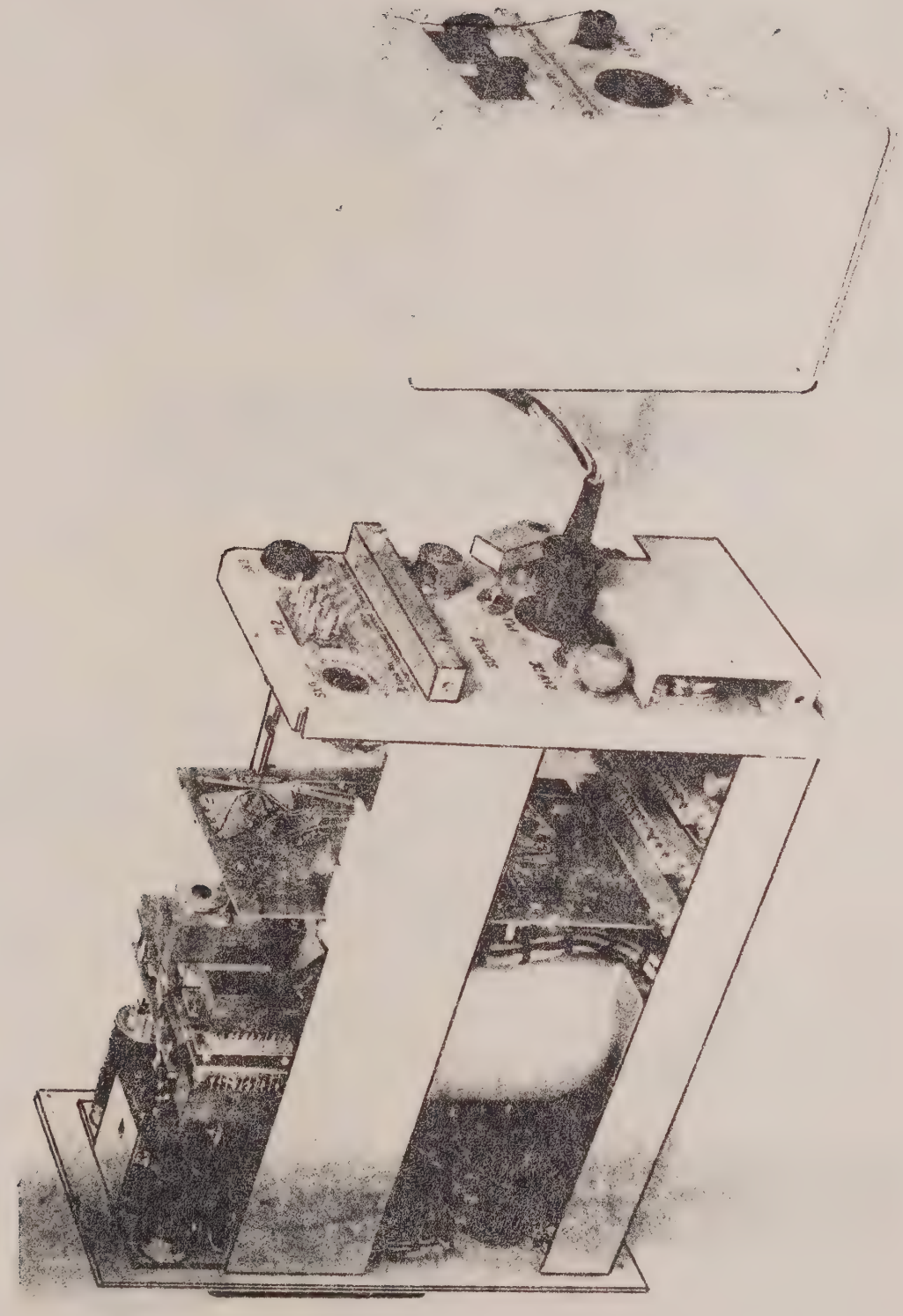


FIG. 3 M1800-H WITH COVER AND POWER SUPPLY REMOVED.

7 TECHNICAL DESCRIPTION

7.1 MECHANICAL CONSTRUCTION - GENERAL

The M1800 basic chassis unit is a U-shaped structure, stiffened by extra side members (see figure 3). Access to the inside is obtained by removing the dust cover, held on by 3 countersunk screws. The front panel and chassis carry the meter, control, wiring etc, but nearly all the active circuits are mounted on plug-in printed circuit boards, or board assemblies, as follows:

(a) The discriminator assembly (type M1810 or M1820) is mounted in a thermostatically-controlled oven, to reduce drift with change of ambient temperature. The oven assembly, complete with boards, can easily be unplugged and removed as a complete unit.

(b) The mixer board (type M4080 or M4110) fits into socket SK2, immediately behind the oven. One or other type of mixer board is always required in this position.

(c) The galvanometer drive board (an optional extra) goes into SK7.

(d) The alarm level board (an optional extra) is fitted in socket SK8. (Associated relays are mounted in the sockets at the back of the chassis). These p.c. boards are coded so that they cannot be inserted the wrong way round, or into the wrong sockets.

The power unit, M1831, is mounted at the rear of the unit, and held on by four 4 BA screws. It is connected electrically through a 6-way plug and socket, and may be completely disconnected and removed, e.g for 24V battery operation of the M1800 unit.

7.2 THE OVEN ASSEMBLY

This assembly contains two printed boards, shaped so that their lower ends can be mounted in a thermostatically-controlled enclosure (see figure 4). The complete unit can be removed from the M1800 chassis by first disconnecting the two sockets SK5 and SK4, in that order (it may be helpful to lift the oven assembly while disconnecting SK4 -the one nearer the front of the instrument). The sockets must be drawn off in line with the p. c. boards; care should be taken not to bend the pins of the plugs. The identifying plug which shows the type of discriminator fitted, must now be removed from the front panel of the M1800 unit. This plug is attached to the oven unit by a short plastic cord; it may be freed by pulling the plug towards the back of the M1800 unit until it clears the front panel, and then pushing down to clear the spring clip, The complete assembly can now be withdrawn from its case, and finally the small yellow oven plug PL3 disconnected (by pulling apart).

The printed board assembly is held into the oven by three 6 BA screws through the split cover plates. Removal of three screws allows the complete assembly to be withdrawn from the oven. The two printed circuit boards can then be separated, by removing the four screws marked 'A' and the tie bar 'B' (figure 4). Finally, the screeb may be slid away from the M4081 board (for the M1810 unit).

When reassembling, take care to replace the various spacing pieces as shown, and ensure that the flying leads to the screen, and from the amplifier board to the top of the oven, are fixed securely.

8 TECHNICAL DESCRIPTION: CIRCUIT DETAILS

8.1 THE TRANSDUCER OSCILLATOR

The input signal to the f-m unit is provided by an appropriate form of oscillator coupled to a transducer. The various forms of oscillator circuit in use are basically similar; though strictly they do not form an integral part of the equipment being described, it will be helpful to describe the operation of a typical circuit.

The circuit given in Drawing No. AM4100/1 is for use with a transducer having a pick-off coil of nominal inductance 30 uH, and producing a 4% change of inductance for maximum input. The circuit uses a silicon transistor Q1 connected into a Clapp-Gouriet* oscillator circuit which operates at about 2 Mc/s; the circuit is designed to work with coils having Q as low as 10. The supply (+10V) to the oscillator circuit is fed down the inner conductor of a 50Ω coaxial cable to the transducer. The base potential of the transistor Q1 is defined by the zener diode MR1, so that the transistor operates at a mean emitter current (about 1·2 mA) fixed by R1. The transistor emitter current and collector voltage are thus accurately defined, which helps to achieve good frequency stability. Amplitude limiting is by current cut-off in Q1; the design is such that Q1 never saturates, which again is desirable for good frequency stability. The output current waveform is thus a series of current pulses at a 2 Mc/s rate, and these are fed down the output cable to the remote M1800 unit. The cable is correctly terminated at the far end, so that the output voltage is nearly independent of the length of cable used.

8.2 THE MIXER BOARD

Two types of mixer board are in use: (a) type M1815 (board No. M4080), which can be used only with the high linearity f-m unit; and (b) type M1816 (board No. M4110) which is designed for use with either

* see ref. 1

high-linearity or wide-band f-m units, and which supersedes the M1815 version. These boards are described separately below.

8.2.1 Mixer Board Type M1815 (Ref. Circuit Diagram M4080/1)

The input to this board is the output signal from a transducer oscillator of the type described (paragraph 8.1 page 22). This signal is amplified and mixed with a local oscillator signal (generated elsewhere). The difference frequency component is extracted and amplified, and appears at the output terminal of the board at a low impedance level and with a defined amplitude.

The supply voltage to the transducer oscillator is fed through the r.f. choke L1; the 2 Mc/s signal from the transducer oscillator is diverted through C1 into the emitter circuit of Q1. The resistor R1, combined with the input resistance of Q1, forms a matched termination for the 50Ω cable. The diode MR1 protects the emitter-base junction of Q1 from damage resulting from short-circuit to earth of the signal input line. (The +10V line is short-circuit-protected: the maximum current which can be drawn is about 300 mA).

The signal appearing on Q1 collector is applied to a double balanced mixer circuit, comprising the transformers T1 and T2 and diodes MR2-5. Here the signal is mixed with the input from the local oscillator, (which is located in the oven assembly), fed in via the amplifier stage Q2. The local oscillator frequency is normally set some 30 kc/s below the input frequency. The output from the mixer is amplified in the cascode stage Q3-Q4, and applied to a Gaussian-response band-pass filter C11-L2-C13. The filter extracts the difference-frequency component, which is of sinusoidal waveform, and lies in the frequency range 30-70 kc/s. The output emitter follower, (Q5) provides impedance reduction and isolation.

The diode MR6 is used to check the presence of a signal at Q5 emitter; in the 'TUNE' position of the M1300 function switch, the half wave rectified output from MR6 supplies to the meter M1 (on the front panel of the unit) a d.c. signal proportional to the output signal amplitude. The amplitude of the output waveform is about 3V p-p; it is largely independent of the amplitude of the input signal, because of the limiter action of the mixer circuit.

8.2.2 The Mixer Type 'U' M1816 (Ref. Circuit Diagram M4110/1)

The input to this board is the 2 Mc/s output signal from a transducer oscillator of the type described above, (paragraph 8.1). The M1816

board produces an amplified and amplitude-limited version of the signal for use with the wide-band discriminator. When the high linearity discriminator (1810) is in use, the local oscillator signal (generated in the M1810 unit) is mixed with the input signal in the M1816 board; the difference frequency component is extracted and amplified, and appears at the output terminal at a low impedance level and with a defined amplitude.

The supply voltage to the oscillator is fed through the r.f. choke L1; the 2 Mc/s signal from the oscillator is diverted through C1 to the terminating resistor R1. The transistor Q1 is connected as a broadly-tuned amplifier stage, the negative feedback from resistor R3 being greatly reduced at and near the resonant frequency of C2-L2 (about 2 Mc/s). The amplified signal appearing at Q1 collector is applied to the emitter-coupled squaring circuit Q2-Q3. The output from Q3 collector is a current square wave, whose amplitude is independent of the input amplitude, but which may be preset by the resistor RV1*. This current square wave is applied to the parallel tuned circuit L8-C10, which restores the sinusoidal waveform. The output of the isolating emitter follower Q5 (set to 0·9 V rms at 2 Mc/s) is used to drive the wide band discriminator, when this is in use.

When the high linearity discriminator (M1810) is installed, however, the action of the M1816 mixer board is slightly different. The signal from the local oscillator in the M1810 unit (set normally to a frequency some 30 kc/s below the input signal frequency) is applied to Q4, which is a tuned amplifier stage exactly like Q1. The emitter-coupled pair then acts as a mixer for the output from Q1 and Q4; the waveform appearing at the common emitters of Q2-Q3 contains a component at the difference frequency, plus various higher frequency components related to the local oscillator and signal frequencies. The latter components are removed by the (Gaussian response) filter C4-L5-C5, and the difference frequency component applied to the amplifier/isolator stage Q6. The output from Q6 is thus a sine wave in the frequency range 30-70 kc/s, of amplitude some 2-3 V p.p.

A check on the presence of signals at the output of the mixer is provided by the diodes MR1 and MR2-3. When the switch S1 of M1800 is in the 'TUNE' position, pin 7 of the mixer board is connected to the front panel meter. Diode MR1 will then deliver to the meter a direct current proportional to the amplitude of the r.f. signal on emitter. MR2-3 will also contribute current if a signal of adequate amplitude is present at the mixer difference-frequency output.

* Not fitted to some earlier pannels.

8.3 THE HIGH LINEARITY DISCRIMINATOR UNIT M1810

This unit consists of two printed circuit board assemblies, mounted partially inside a temperature-controlled enclosure. The unit may be removed from the M1800 chassis by disconnecting three plugs. The two assemblies are the High Linearity Discriminator board (M4081), and the Amplifier/Oscillator board (M4085); these are described separately below.

The high linearity discriminator unit may be used in any type of M1800 chassis, and with either the M1815 or M1816 mixer board. When installing a new discriminator unit in an M1800 chassis, it is desirable to readjust the SET SENS control on the M1800 (see paragraph 8.6.2 page 31), to standardise the sensitivity of the complete equipment.

(Note: the body of the oven is connected to the -7 V line, not to earth).

8.3.1 The High Linearity Discriminator Boad (M4081)

This circuit is basically a linear frequency-to-voltage converter, using a saturating toroidal core in a constant area pulse generator circuit. The circuit is mounted on a printed board, shaped so that the temperature sensitive components can be maintained at a constant temperature in an oven. The input signal is derived from the mixer board, as described above, and is a sine wave of amplitude about 3 V pp, and in the frequency range 30-70 kc/s. (This signal is fed from the mixer board via the jack socket SK3 at the rear of the M1800 unit; this socket may be used to monitor the difference frequency, and/or to break the connection between the mixer and discriminator if required).

The input signal to M4081 is applied to Q1, which forms part of the squarer circuit Q1-Q2-Q3. Q1-Q2 form an emitter-coupled pair; the input signal amplitude is large enough so that Q1 is alternately cut off and turned full on, so Q3 is alternately cut of and bottomed. The waveform on Q3 collector is thus a rectangular wave swinging between levels of -7V and about OV. The filter R8-C2 feeds the mean voltage on Q3 collector back to Q2 base; the negative feedback loop so formed tends to hold Q2 base at the same mean potential as Q1 base. RV1 controls the potential of Q1 base, so that variation of RV1 slider position will alter the mark/space ratio of the waveform on Q3 collector. Normal adjustment is for a 1:1 ratio, for reason given below.

Transistors Q4-7 form a (non-regenerative) switching circuit for driving the saturating magnetic circuit T1. Q4 and Q7 form an emitter-coupled pair; Q4 is fed with the square wave output from Q3 collector,

so that current from the common emitter resistor R10 flows alternately into Q4 and Q7 collector circuits. When, for example, Q4 is on, Q5 base potential falls below zero volts, and is caught by diode MR2, thus Q5 is cut off, while Q6 is bottomed by current through R13. One half cycle later, the situation is reversed.

A constant current (of about 110 mA), derived from the M1800 power supply, is fed into the centre tap on the primary winding of T1, and flows through one or other half of the winding, depending on whether Q5 or Q6 is conducting at the time. This current is large enough to saturate the core. Considering the situation when e. g Q6 has just been turned on; the core of T1 was previously saturated in (say) the negative direction, but now the magneto-motive force has been reversed, the voltage across the core rises until limited (to about 7 V) by the zener diode MR4. The flux in the core now increases, at a constant rate defined by MR4 voltage and the number of turns on the core, until positive saturation is reached. At this point, the voltage across the winding collapses, and the core remains saturated until the next current reversal in the primary. The area of the voltage pulse occuring across the windings of T1 is a function only of the saturation flux levels in the core and the number of turns in the primary winding. Thus the output from the secondary winding is a series of alternately positive and negative-going constant duration* voltage pulses, two per cycle of input frequency. This output is full-wave rectified by the bridge MR5-8; the constant current transistor Q8 clamps the output voltage to earth level between pulses, thus removing any tendency to peak rectification. The waveform on Q8 collector is applied to the 9th order Gaussian filter M4086 (mounted on a separate sub board), via the matching resistor R17. The output from the filter is thus a voltage directly proportional to frequency. The pass-band of the filter is 0-10KHz; the lowest carrier frequency is 30 kc/s, but this is increased to 60 kc/s by the frequency-doubling action of the core circuit. Adjustment of the mark/space ratio of the input waveform to unity (see above) minimises the 30 kc/s component in the output from the filter.

The output from the M4081 board, appearing across a 5 kΩ resistor terminating the M4086 filter, is approximately -4V at 30 kc/s, -7V at 50 kc/s, and -10V at 70 kc/s.

When assembled and fitted inside the oven, the discriminator is surrounded by a screen to reduce interation between the discriminator and the local oscillator. A small amount of interation remains; it shows up in the form of small increases in noise level at certain settings of the SET ZERO control.

* Pulse duration is about 4•5 μ sec.

8.3.2 The Amplifier/Oscillator Board (M4085)

(Refer to circuit diagram M4085/1). This board contains three quite distinct circuits:

(a) The output d.c. amplifier (Q1, Q3, Q4). This is a simple unity gain parallel feedback amplifier, which provides isolation, impedance transformation and offset. The output from the discriminator board (M4081) is applied, via the filter terminating resistor R1, to the amplifier virtual earth point. RV1 and R2 provide a bias current, which shifts the centre level of the signal from -7V at the input to zero at the output. Resistor R3 allows a calibration voltage to be added algebraically to the signal (see paragraph 6.5).

(b) The local oscillator circuit: Transistor Q6 is connected in a Clapp-Gouriet circuit. The voltage-controlled capacitor C12 allows the local oscillator frequency to be remotely controlled, over the approximate range 1·9-2·1 Mc/s. The bias voltage for C12 is normally provided by the 10-turn SET ZERO potentiometer on the M1300 unit, which delivers a preset fraction of the +7·5 reference voltage appearing across the diodes MR1-MR2.

(c) The power supply control circuit comprises the two transistors Q4-Q5, connected as a difference amplifier which compares a fraction of the +10V line voltage with the voltage of the zener diode MR3. The collector current of Q4 controls the output of the power supply circuit, as described below (paragraph 8.5). The preset control RV2 is set to give 10V ± 0·1V on pin 18, relative to pin 16.

8.4 THE WIDE BAND DISCRIMINATOR UNIT (M1820)

The unit comprises two printed circuit boards, mounted partially inside a temperature controlled enclosure. The unit may be completely removed from the M1300 chassis by disconnecting three plugs. (see paragraph 7.2). The two printed boards are the Wide-band Discriminator (M4082 and the d.c. amplifier M4111). Their operation is described below.

Note that the M1820 unit should only be used (a) in conjunction with the M1816 (M4110) mixer board, and (b) in later model M1300 units having revised wiring looms, such as the M1300B. (Suitable units are easily identified because they are fitted with metal covers to sockets SK4 and SK5).

(Note: the body of the oven is connected to the -7V line, not to earth).

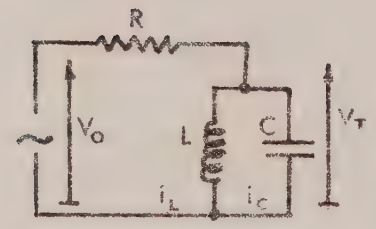


Fig 5a Basic Circuit

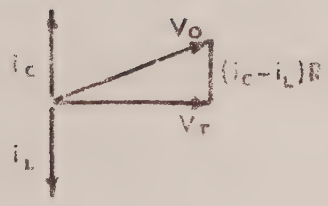


Fig 5b

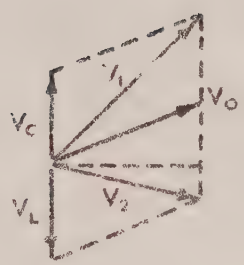


Fig 5c

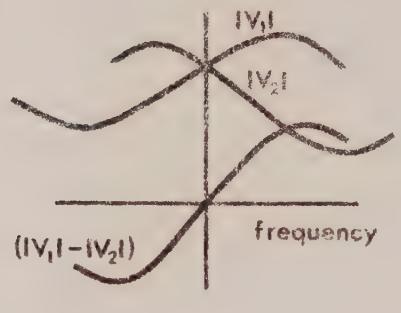


Fig 5d Discriminator Characteristic

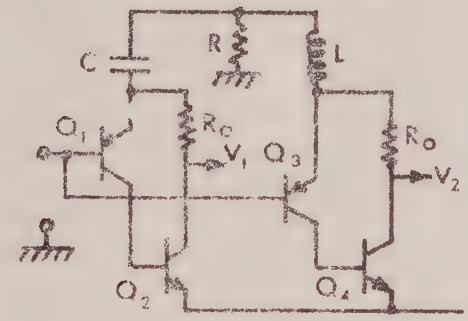


Fig 5e Simplified Circuit

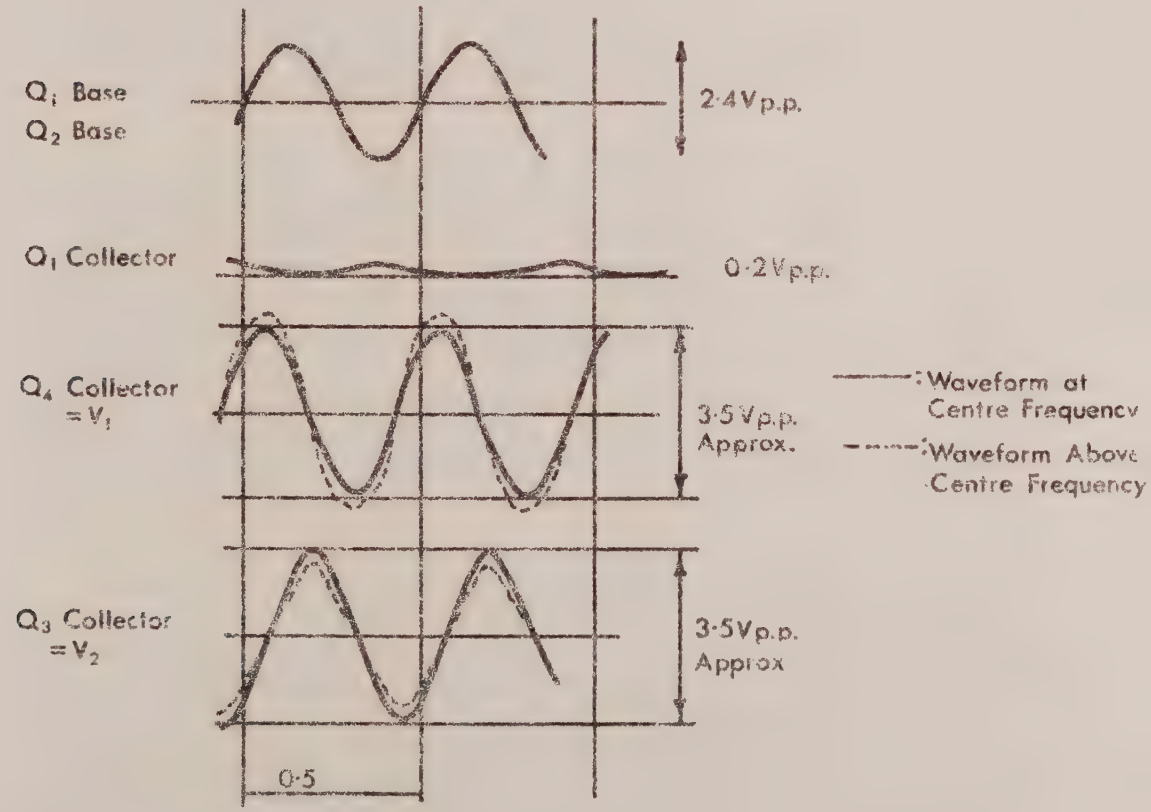


Fig. 5f Waveforms (M 4082 Board)

FIG. 5 WIDE BAND DISCRIMINATOR DETAILS

3.4.1 The Wide Band Discriminator (M4032)

This circuit is a frequency-voltage converter whose centre frequency is adjustable over the range 1·9-2·1 Mc/s, and which produces its full output voltage swing for a change of 2% in input frequency. The circuit design is unconventional (ref. 2); its operation depends on the properties of a single parallel tuned curcuit (fig. 5a). A voltage v_o at frequency f is applied to a nominally loss-less parallel tuned circuit LC, of resonant frequency f_o. When $f = f_o$, the reactance of C is equal to the reactance of L, so that the current i_C is equal to, but in antiphase with, the current i_L (because i_C and i_L respectively lead and lag the voltage v_t by 90°). Thus the vector sum of i_C and i_L is zero, and (ideally) no current flows through R, so v_t is equal to the input voltage v_o. At frequencies above f_o, i_C increases and i_L decreases, so there is a resultant component in phase with i_c, which flows through R and produces an amplitude and phase difference between v_o and v_t. This phase change is converted into an amplitude change as follows. The voltage v_o is added separately (a) to a voltage v_c proportional to i_c, to produce a voltage v_1, and (b) to a voltage v_L proportional to i_L, to produce a voltage v_2 (see fig. 5c). It is clear that the amplitudes of v_1 and v_2 will be equal at f_o, and vary differentially with frequency as shown in fig. 5d. If v_1 and v_2 are rectified separately and the resulting outputs are subtracted, the frequency-discriminator characteristic curve shown in fig. 5d is obtained.

The circuit used to perform this operation is shown in simplified form in fig. 5e. Q1 acts as an emitter follower, whose performance is improved by a negative feedback loop including transistor Q2. Thus the input voltage v_o will appear at Q1 emitter unchanged in amplitude or phase, and a very low impedance level. The current i_C through the capacitor will flow almost entirely through the resistor R_o, because the feedback loop holds the emitter current of Q1 almost constant. Thus, the voltage at the lower end of R_o will be the vector sum of v_o and $(i_c . R_o)$, which is the quantity called v_1 above. The voltage v_2 is obtained in the same manner from a second circuit Q3-Q4.

In the complete circuit (drawing M4032/1), the tuned circuit is formed by L7 and C7; C8 is a voltage variable capacitor providing remote tuning, and R9 and RV1 provide the damping resistor R. The two detectors Q5 and Q6 provide direct current outputs proportional respectively to the voltages v_1 and v_2. The difference between the currents is fed into the Gaussian 7th order filter L8-10, C12-17, so the output voltage appearing across the load resistor R16 varies with frequency as shown in fig. 5d. The waveforms in the circuit are as shown in fig. 5f. The filter bandwidth is 0-120 kc/s, but the finite bandwidth of the tuned circuit L7-C7 restricts the overall frequency response to about 0-70 kc/s.

8.4.2 The Amplifier Board (M4111)

(Refer to the circuit diagram M4111/1). This board contains two separate circuits:

(a) The output d.c. amplifier (Q3-Q6). This is a simple parallel feedback amplifier which provides isolation, impedance transformation and offset. The output from the discriminator board M4082 is applied, via the filter terminating resistor R6, to the amplifier virtual earth point. RV2 and R5 provide a bias current which allows the amplifier zero to be adjusted. (The base of Q4 is returned to a positive voltage of 0·6 V to ensure that adjustment is possible in both directions about zero). Resistor R7 allows a calibration voltage to be added algebraically to the signal (see paragraph 6.5).

(b) The power supply control circuit comprises the two transistors Q1-Q2, connected as a difference amplifier which compares a fraction of the +10 V line voltage of the Zener diode MR1. The collector current of Q1 controls the output of the supply circuit, as described below (paragraph 8.5). The preset control RV1 is set to give 10 V ± 0·1 V on pin 13, relative to pin 16.

8.5 THE STABILISED POWER SUPPLY CIRCUIT

(Refer to M1800B/1 circuit diagram).

The control amplifier for the stabilised power supply circuit is mounted in the oven assembly, while the remainder of the circuit is built into the rear part of the M1800 unit. The circuit is fed from a nominal 24 V d.c. supply, normally derived from a mains power unit such as the M1331, which provides a unstabilised full-wave rectified output voltage containing some 5% ripple at full load. When a battery is used, MR4 protects the unit against accidental reversed connections to the supply. The supply switch S 3 operates for both mains and battery operation, as it switches the mains input with one pole and the 24 V line with the other. As already described in sections 8.3.2, the oven assembly contains a differential amplifier which compares the voltage of a Zener diode with a fraction of the +10 V line voltage. The amplifier output is connected to Q1 (circuit M1800 B/1), which in turn controls the series power transistor Q3. The current supplied by Q3 to the +10 V line passes through the two diodes MR1-2; the voltage drop across these diodes is used with R9 to define the current into the auxiliary constant current transistor Q2, which supplies the high linearity discriminator circuit (see paragraph 8.3.1).

The -7V line is produced by passing part of the supply current through the power zener diode MR5. This provides a supply line of moderate stability and low impedance. (The current drawn from the -7V line must of course be less than the total load current in the +10V line, otherwise the Zener diode will cut off).

Both the +10V and -7V lines are short-circuit-proof. As the current drawn from the +10V line increases, transistor Q1 is turned on more fully, until at last diode MR2 cuts off and the collector current from Q1 is determined largely by R11. This limits the current which can be drawn to some 300 mA. The short-circuit current for the -7V line is limited to the current drawn by the +10V supply, of course.

Up to three M1800 units may be run in parallel from the same 24V battery, if required; this method of connection means that the three MR5 Zener diodes will now be connected in parallel, so that the total load current from all three units will flow through the lowest voltage diode. The diode rating is such that this is satisfactory. No interaction between units results.

For mains operation, the supply rails to the circuits are provided from a d.c. supply, and the oven heater power from a 24V a.c. supply. On battery operation, the d.c. supply and oven heater are connected in parallel by the switch S2, at the rear of the unit. (S2 cannot be operated until the supply lead from the M1831 unit is withdrawn). To reduce battery drain, S2 may be left in the 'off' position, so that the oven heater is not in circuit; this of course reduces the warm-up time, but the long-term drift will be worse. The power supply will operate satisfactorily for voltages in the range 20-28V d.c. but the oven requires 24V ± 10% for correct operation.

8.6 SETTING-UP PROCEDURES

8.6.1 General

The various preset controls on the M1800 equipment, and particularly those fitted to the M1810 and M1820 discriminator units, are carefully adjusted in the factory, and it is unlikely that they will require adjustment in the field. The most common requirement will be for adjustment of the SET SENS control (at the rear of the M1800 unit), which will generally be necessary whenever the discriminator unit is changed.

This section contains information on how the various preset controls should be set up. It is essential to use the correct test equipment, if satisfactory results are to be obtained; however, the equipment required is not specialised, and is in fairly general use.

3.6.2 Setting Up the M1810 Discriminator Circuit

The only adjustments provided on the M1810 unit are for noise level and bias level. The voltage output change resulting from a 40 kc/s change in input frequency is specified as 6V ± 10%; this is converted into a uniform full-scale meter deflection, by adjustment of RV4 on the M1800 chassis. The following setting-up procedure is used at the factory to ensure that the M1810 unit is correctly adjusted, when installed in a particular M1800 chassis. In all cases, the oven assembly should be allowed to warm up for half an hour before final adjustments are made.

(a) Noise level. This is set up using a 3V p-p 30 kc/s input signal applied to the discriminator. The signal may be connected to the ring of a 3-way jack plug inserted in socket SK3. (Alternatively, if no signal generator is available, connect a transducer oscillator to the M1800 INPUT socket; monitor the difference frequency, using a counter connected to SK3 via a 3-way jack plug with tip and ring linked. Use the SET ZERO control to set the frequency to 30 kc/s ± 40 c/s).

Viewing the signal at M1800 OUTPUT socket, adjust RV1 on the M4081 board (accessible through hole A on the M1800 dust cover) for minimum noise (the level should be below 15 mV p-p).

(b) Bias level. Apply to the M1810 discriminator input a signal at 50 kc/s ± 40 c/s (use either of the methods described at (a).) Adjust RV1 on the M4085 board (accessible through the hole 'B' on the M1800 dust cover) so that the meter reads 0 on the red scale. (it is assumed that the mechanical zero of the meter was checked while the instrument was switched off).

(c) Sensitivity. Alter the input frequency to 30 kc/s ± 40 c/s. Set METER SENS (on M1800 front panel) to the fully anticlockwise position. Adjust SET SENS (at rear of M1800: remove M1831 power unit to gain access) so that meter reads 0 on black scale. Now change input frequency to 70 kc/s ± 40 c/s. The meter should read 100 ± 1 on black scale.

3.6.3 Setting Up the M1820 Discriminator Circuit

The discriminator circuit used in this equipment contains only a

a single tuned circuit, which reduces the number of possible adjustments to three: tuned circuit centre frequency. tuned circuit Q, and output d.c. bias.

Coarse adjustment of the centre frequency is provided by the tuning slug in coil L7 (M4082 circuit), while fine tuning is of course controlled by the voltage-variable capacitor C16. The tuned circuit Q is controlled by RV1 (normally set fully anticlockwise). The output bias is taken out by the control RV2 on the d.c. amplifier board M4111.

Setting-up the discriminator requires adjustment of the tuned circuit centre frequency and d.c. bias controls to ensure that the most linear part of the discriminator characteristic is used, and the correct tuning range is covered. The following procedure is recommended.

8.6.3.1 Equipment Required

2 Mc/s counter
2 Mc/s oscillator and 200 d.c. oscillator
Valve voltmeter

8.6.3.2 Initial Settings

(a) Check mechanical zero of meter, on red scale.

(b) Apply 240 V a.c. to power supply unit. Switch on, and leave for 30 minutes. Check that pilot and oven bulbs are on. (Note that oven bulb goes off and on as oven cycles).

(c) Measure +10 V line (pin 11 on SK7 or 8), relative to earth (pin 13). Adjust RV1 (round pot.), on M4111 in oven assembly, to give 10 V ± 0·1 V.

8.6.3.3 Linearity

(a) On M1800, switch to TUNE. With no input, meter should indicate between +6 and +14 on red scale.

(b) Connect signal of frequency 2·1 Mc/s ± 0·1 kc/s, amplitude greater than 200 m V p-p, to INPUT socket (a.c. coupled). Meter reading should increase to about double.

(c) Switch to REF. Set meter to 0 on red scale, using SET REF control. Unplug M4082 board (SK4). Measure the d.c. voltage relative to earth on pin 15 of M4111 board; adjust RV2 (multi-turn preset pot) on M4111 until the d.c. voltage at this point is within 0·05 V of earth. (This operation removes any d.c. bias on the amplifier). Replace connection to M4082 board.

(d) Switch to SIG. Turn SET ZERO control fully anticlockwise. Adjust coil tuning slug on oven assebly until the d.c. voltage at M1300 output socket falls to zero.

(e) Apply a 200 c/s signal to PL2, pin 9 (at rear of f.m. unit. Make the connection via a series 2·2 kΩ resistor and isolating capacitor of 0·1 uF).

Measure (on the valve voltmeter, or CRO) the amplitude of the 200 c/s signal now present at the OUTPUT socket of the M1300.

Adjust the 200 c/s input signal amplitude until the signal at the output socket is in the range 50-300 m V p-p. Call this level v_1.

(f) Note frequency of signal applied to M1300 INPUT socket (nominally 2·1 Mc/s); increase this frequency by 20 kc/s (± 1 kc/s) and note that new value of the amplitude of the 200 c/s waveform at the OUTPUT socket (say v_2). Now decrease the frequency of the INPUT signal until it is 20 kc/s below the original frequency, and again note the amplitude of the OUTPUT signal (say v_3).

THEN, FOR THE SPECIFIED LINEARITY (± 1%), the values of v_2 and v_3 must be greater than 90% of v_1. If this is not the case, see (g) below.

(g) If amplitude of v_2 or v_3 falls below $0{\cdot}9\,v_1$ at one end of the scale, proceed as follows:

1. Return meter to 0 on red scale by adjusting f_{in}. (f_{in} is nominal 2·1 M c/s)

2. Turn zero set (FV2) on M4111 board so that meter needle moves some 10 divisions towards the end of the scale which gives low output (v_2 or v_3).

3. Reset f_{in} to give a meter reading of 0 on red scale.

4. Now repeat step (f) above. Linearity should be better; if improvement is not sufficent, then repeat 1. and 2. above.

(h) Now reset coil tuning slug to give zero voltage (± 0•1 V) at the OUTPUT socket of M1800 for f_{in} = 2•10 Mc/s. Lock the slug (without disturbing the setting). Disconnect the 200 c/s signal from the rear of the M1800.

3.6.3.4 Sensitivity

(a) Set the frequency of the signal applied to the INPUT socket to 2.000 Mc/s (+ 100 c/s). Adjust the SET ZERO control to give 0 ± 0•1 V d.c. voltage at the OUTPUT socket.

(b) Change the input frequency to 2•02 Mc/s ± 100 c/s, and check that V_{out} lies in the range +2•7 to ±3•3 volts, d.c. Set SET SENS (RV4, at rear of M1800 -behind power unit) so that meter reads 100 on black scale.

(c) Now change input frequency to 1•98 Mc/s ± 100 c/s, and check that meter reads 0 ± 1•5 on black scale.

(d) Check that readings are not affected by touching the oven assembly, socket covers, etc. Disconnect input signal.

3.7 REFERENCES

Ref 1: J.K. Clapp: Frequency Stable L-C Oscillators Proc. I.R.E. 42, 8, August 1954, pp 1259-1300.

Ref 2: J. Willis: New Frequency Discriminator Circuit Electronics Letters 1, 7, September 1965, pp 194-5.

9

FAULT FINDING SECTION

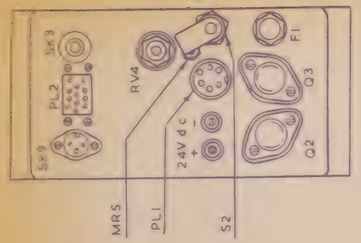
	Symptom	Possible Cause	Action
1	Press SUPPLY switch Supply and Oven lights do not come on.	No mains supply voltage Fuse F1 blown in M1331 Power Unit (N. B: on 24V operation, with oven switched off by S2 at rear of M1800, neither supply nor oven lights will operate).	Check at supply socket and at M1831 input plug. Check fuses.
2	Switch to REF: turn METERRSENS (top right of front panel) fully anticlockwise.		
2a	Turn SET REF until meter reads zero then turn anticlockwise 2 1/2 turns. Meter should read below 0 on 100 scale. If meter deflection is in range 10-50.	Partial s/c on -7 V line.	Check that connection to OUTPUT socket is not s/c to earth.
2b	Turn SET REF until meter read zero then turn clockwise 2 1/2 turns. Meter should read over 100 on black scale. If meter deflection is in range 50-90.	Partial s/c on +10 V line.	Check that connection to INPUT and OUTPUT sockets are not s/c to earth.

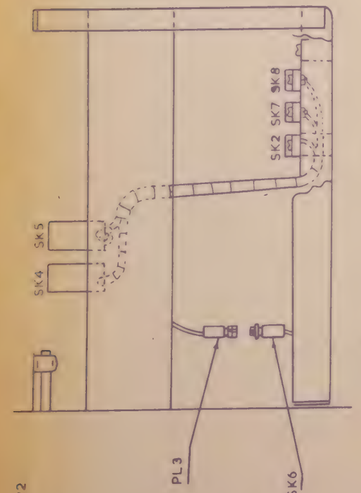
2c	Meter reading fluctuates	Noisy METER SENS pot. Check by turning pot, and observing if fluctuations are worse at certain positions (N. B: turning pot increases meter deflection).	Replace potentiometer RV3.
3	Switch to TUNE. (ensure that METER SENS control is fully anticlockwise).		
3a	Remove any connection to INPUT socket. Meter should read between 56-64. If meter reads 50 (on black scale):	Mixer board not installed, or not plugged in properly.	Check mixer board, by replacement if possible.
3b	Connect transducer oscillator to INPUT socket. Turn SET ZERO fully clockwise, then turn back. Meter reading should increase to greater than 70 at some position. If not increase:	Transducer oscillator not working.	Try another oscillator.
	If reading decreases to 50 on connecting oscillator:	Cable to transducer oscillator has s/c to earth.	Check cable and plug.

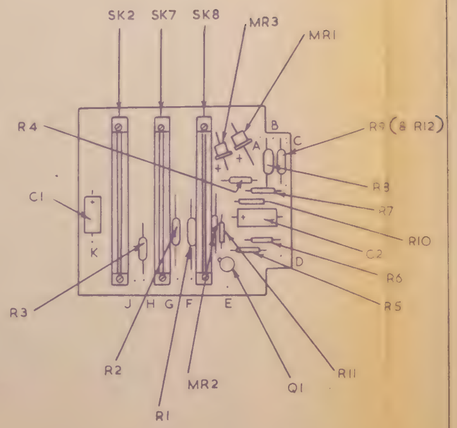
High Linearity M1300

4	Switch to SIG position. Use SET ZERO to bring meter needle on scale.		
4a	If meter needle remains below 0 on black scale at all times:	No signal into discriminator: faulty jack socket connection.	Check that SK3 (rear of M1300) has no jack inserted, or that any jack used has s/c link between tip and ring.
		Faulty mixer board	Check by replacement: or check that signal on tip of jack is 3 V pp amplitude, and in frequency range 30-70 kc/s.
		Faulty M4081 board in discriminator.	
4b	If meter needle moves in reverse sense to SET ZERO pot:	LO frequency is too high	Turn SET ZERO clockwise: meter needle will go below 0, then return moving in correct sense.
4c	Noise level high		
	(a) Meter set to 0 on black scale	Wrong setting of RV1 on M4081 board in M1810 discriminator assembly (accessible through hole A in M1300 cover.)	Adjust RV1 for min. noise (N. B: ensure M1800 has had 1/2 hour to warm up).

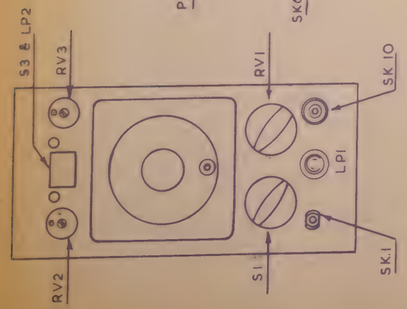
	(b) Motor at above 20 on black scale. Noise level depends markedly on SET ZERO position.	Interaction between M4035 local oscillator and M4081 discriminator. (N.B: this effect is always present to a small extent.)	Check C5 on M4085 (connected to oven body). Ensure that screws holding discriminator assembly into oven are tight.
	Wide Band M1800		
5	Switch to SIG position. Use SET ZERO to bring meter needle on scale. If meter needle remains at setting near zero on red scale.	No signal to into discriminator Faulty transducer oscillator Faulty mixer board. Faulty M4032 board in M1820 discriminator assembly.	Check by replacement. Check by replacement.

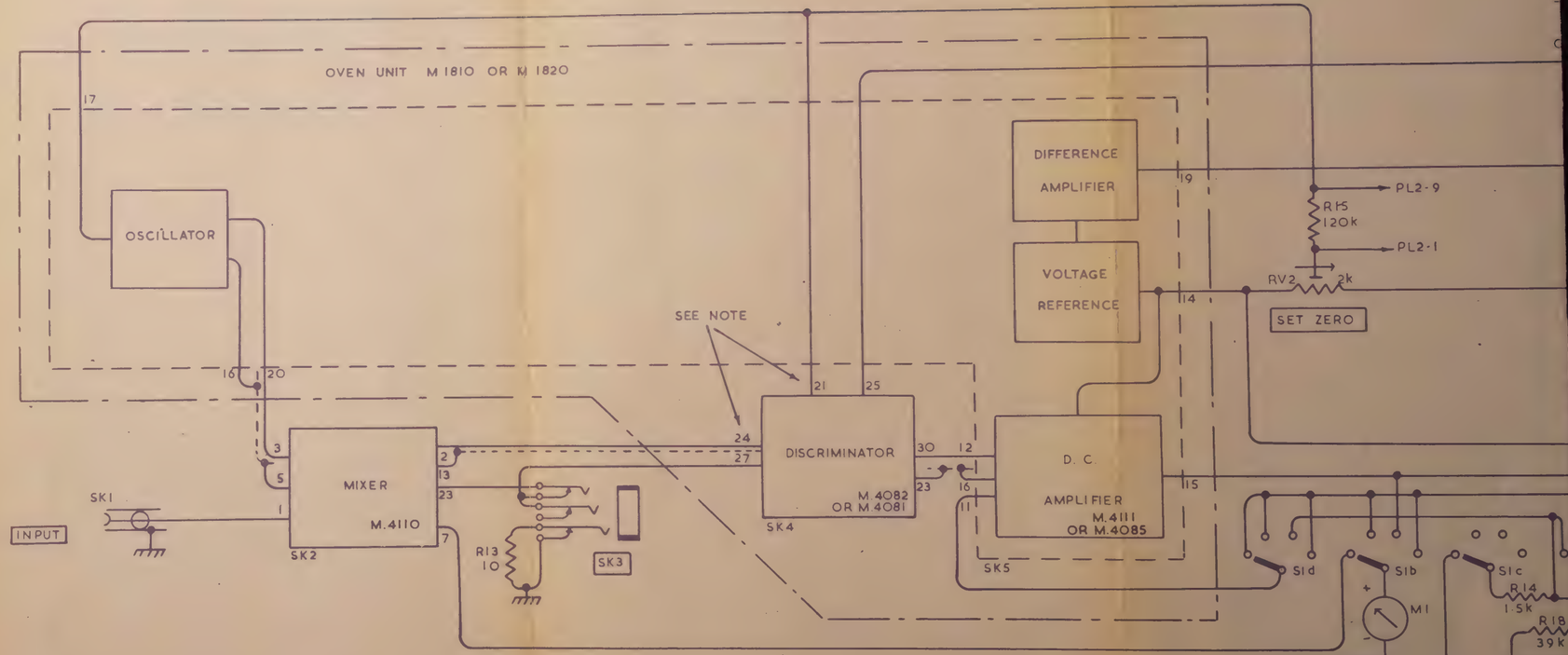






M 4087 EDGE CONNECTOR BOARD





NOTE:- 1) OSCILLATOR IS PART OF M4085 ONLY.
2) TERMINATIONS 21 & 24 ARE USED ON M.4082 BUT NOT ON M.4081.

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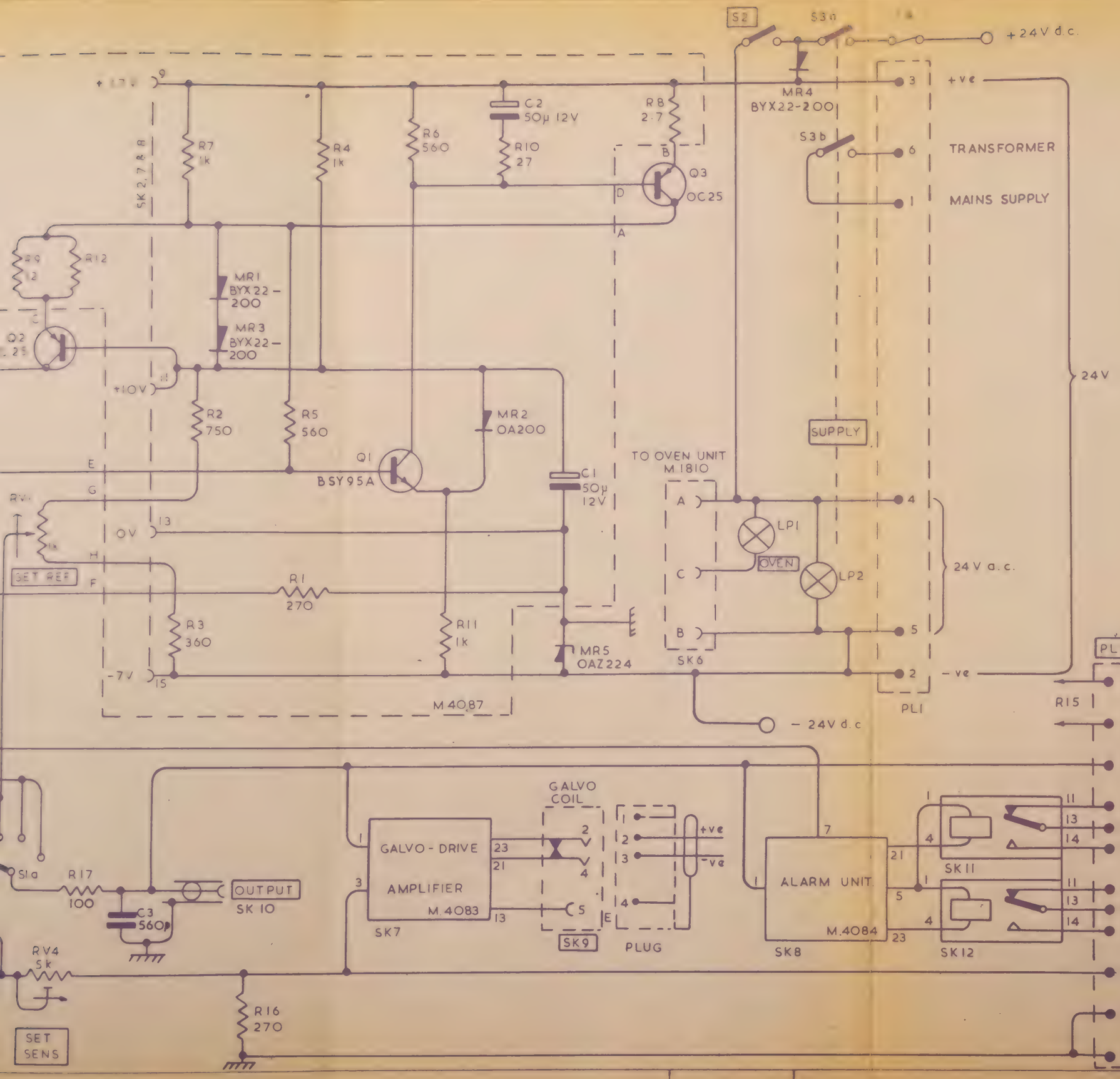
S2
S3a
S3b
+24V d.c.
MR4
BYX22-200
+ve
TRANSFORMER
MAINS SUPPLY
24V
SUPPLY
+17V
9
SK 2,7 & 8
R7
1k
R4
1k
R6
560
C2
50µ 12V
R10
27
R8
2·7
Q3
OC25
B
D
A
R9
12
R12
MR1
BYX22-200
MR3
BYX22-200
Q2
+10V
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750
R5
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MR2
OA200
Q1
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C1
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SET REF
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270
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360
R11
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15
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TO OVEN UNIT
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9
EXT. TUNE
R15
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5
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7
11
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4
8
12
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LOW ALARM
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OUTPUT
SK 10
RV4
5k
SET
SENS
R16
270
GALVO - DRIVE
AMPLIFIER
M.4083
SK7
3
1
23
21
13
GALVO
COIL
2
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SK12
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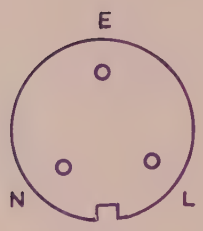
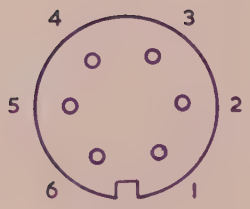
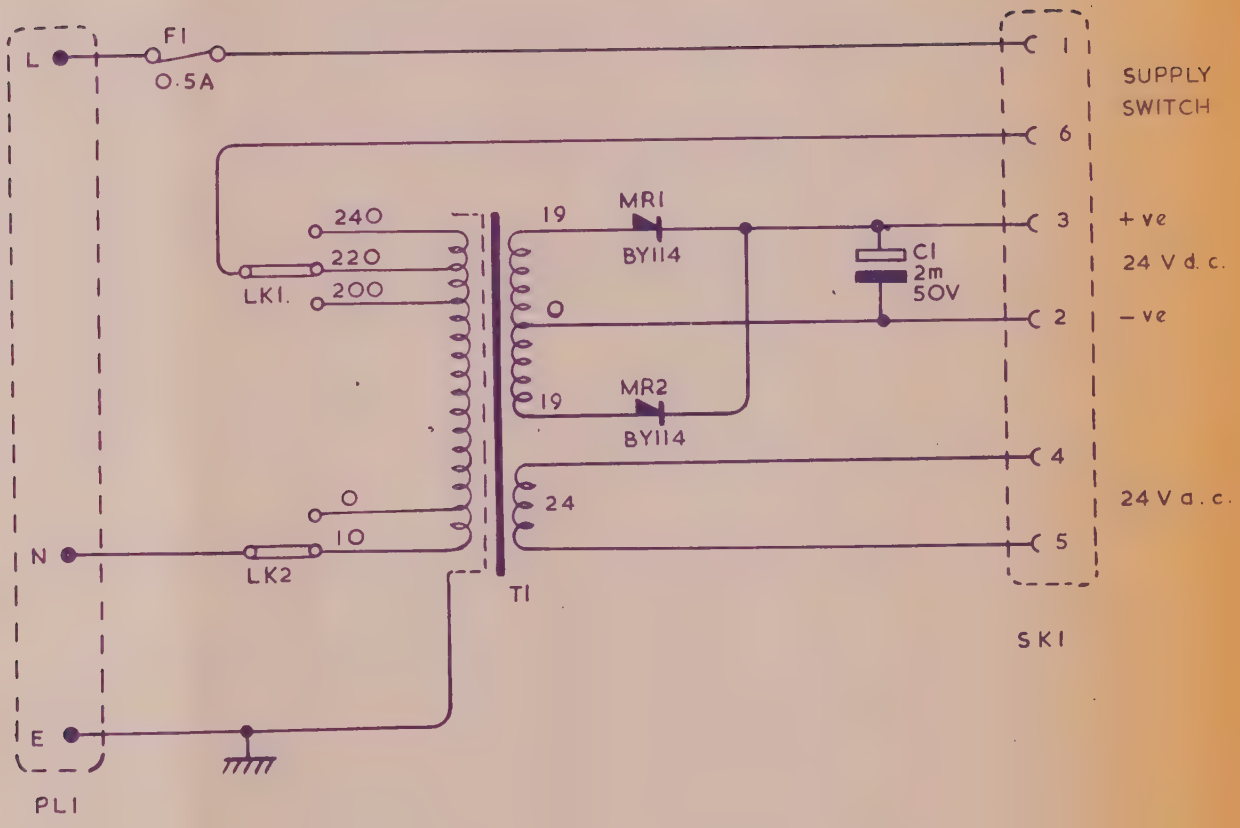


PL1



SK1

REAR VIEWS.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C1
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50V
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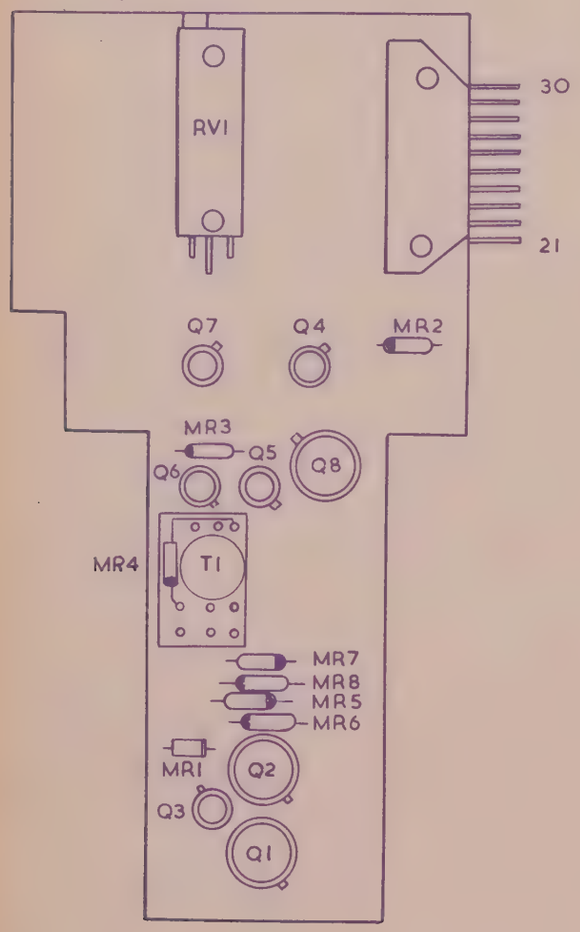

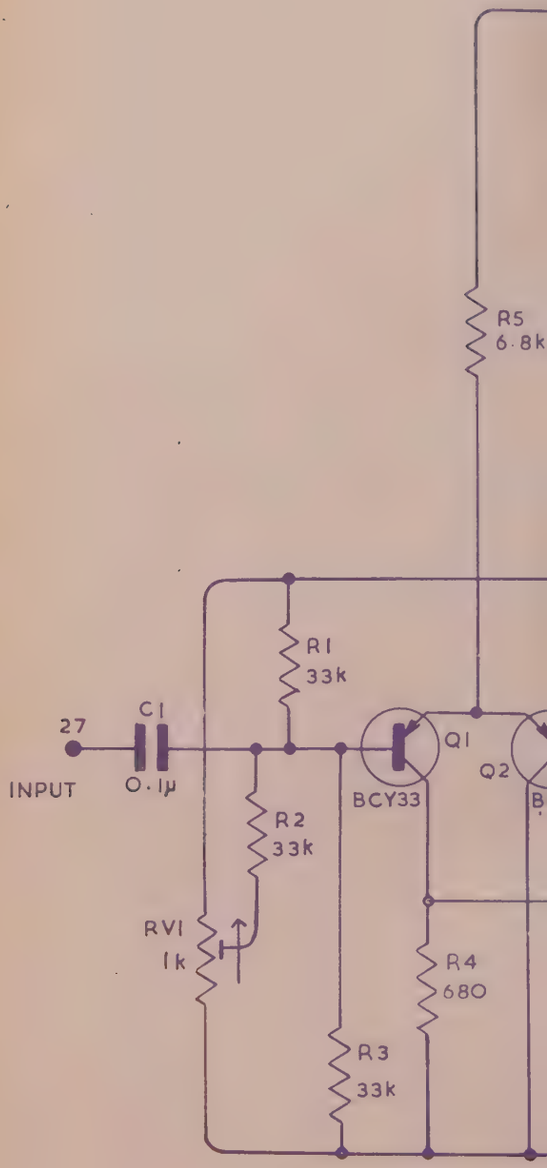

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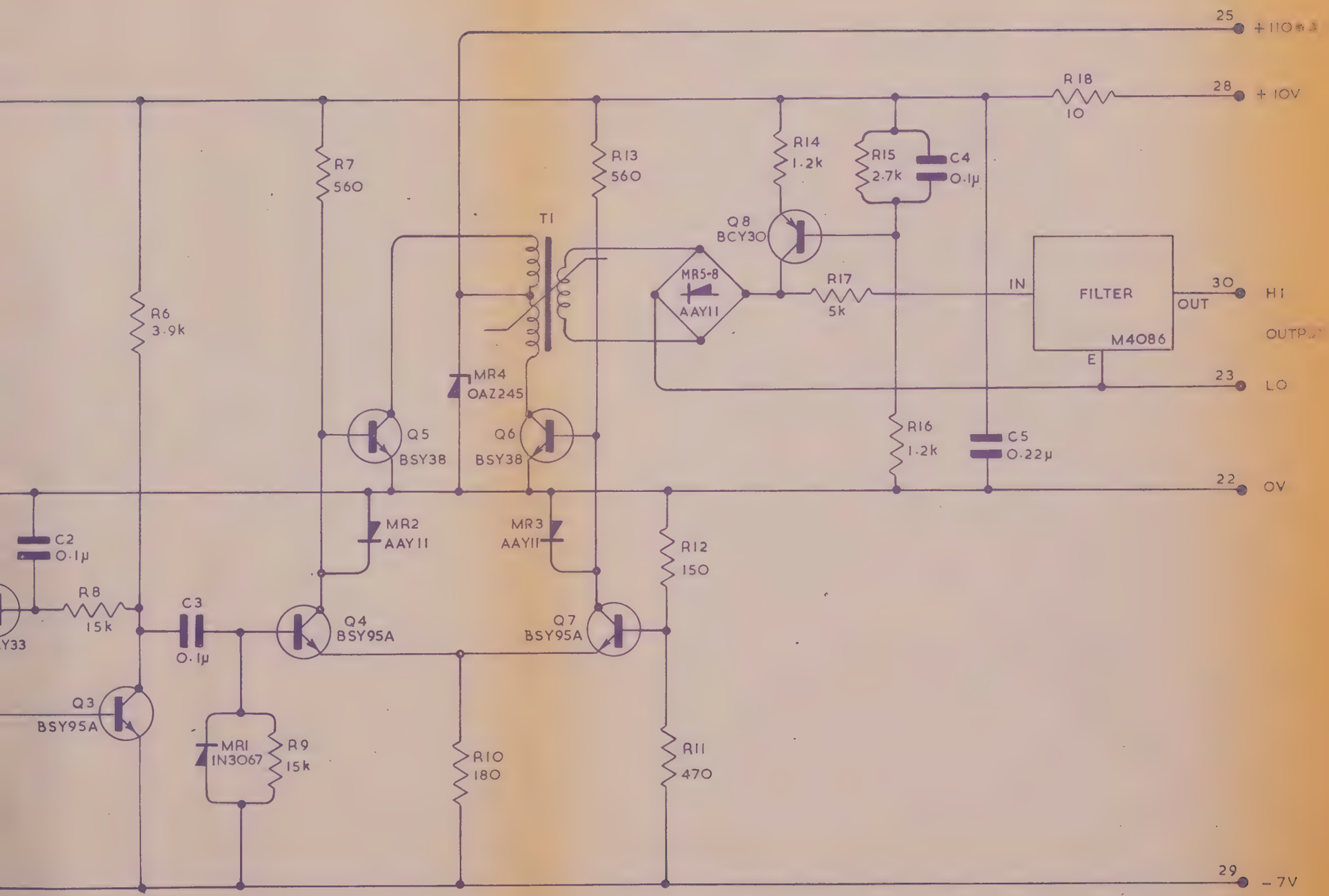
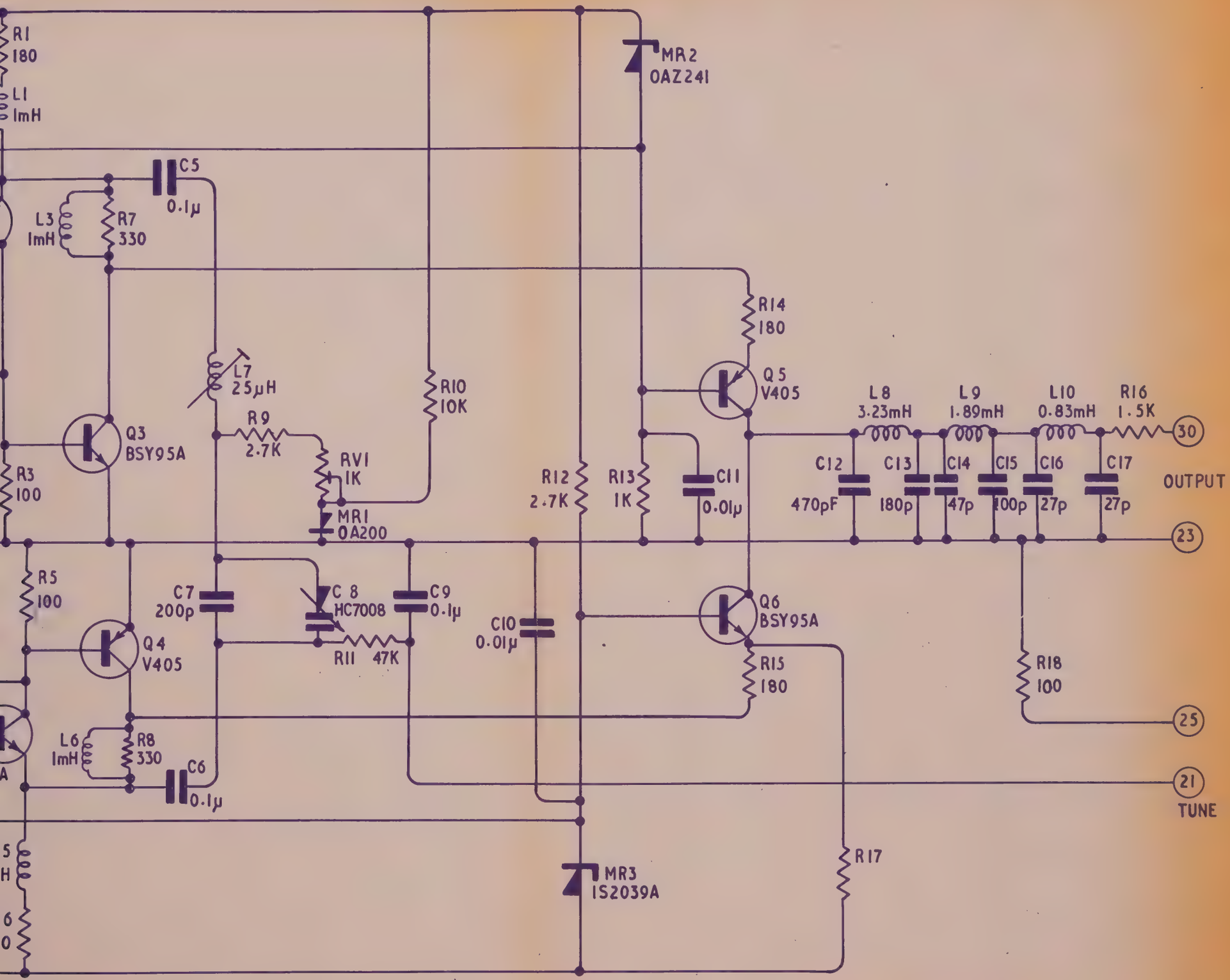
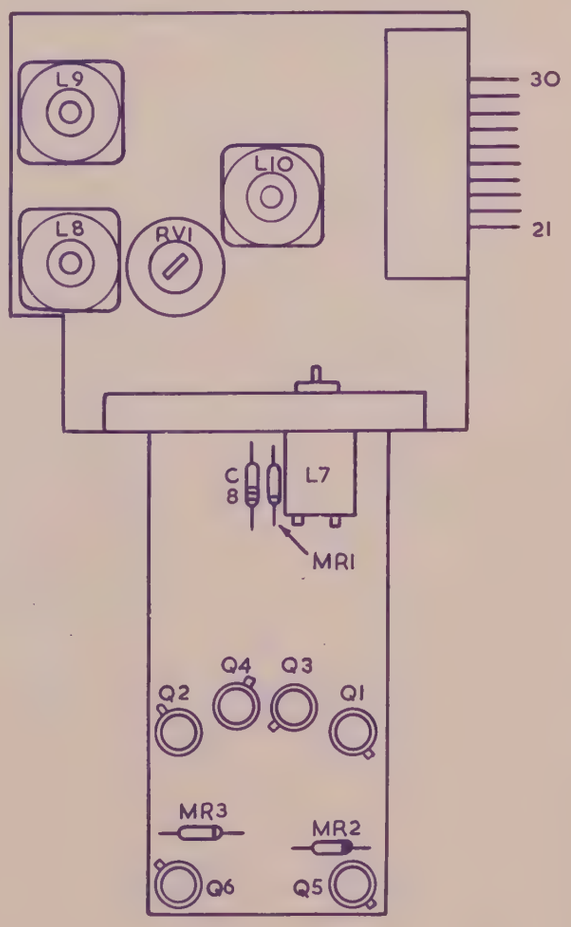
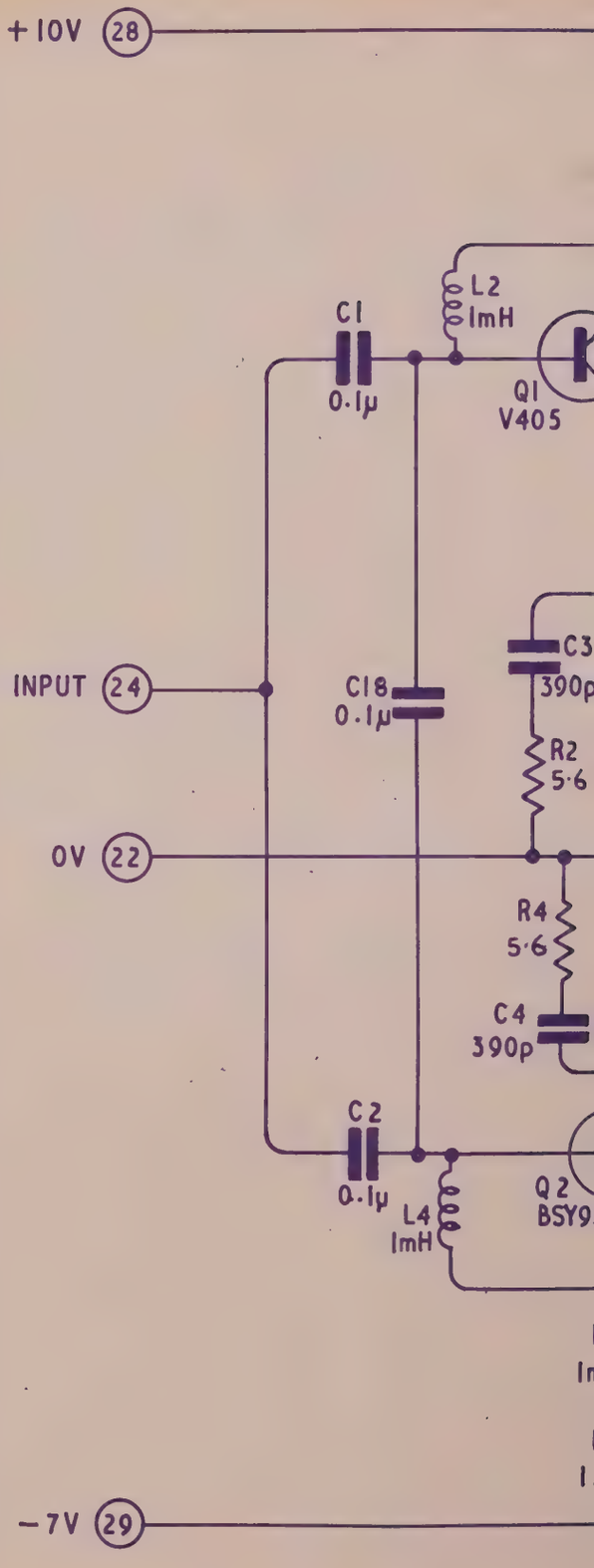


HIGH LINEARITY DISCRIMINATOR M.4081/1



WIDE BAND DISCRIMINATOR | M4082/1





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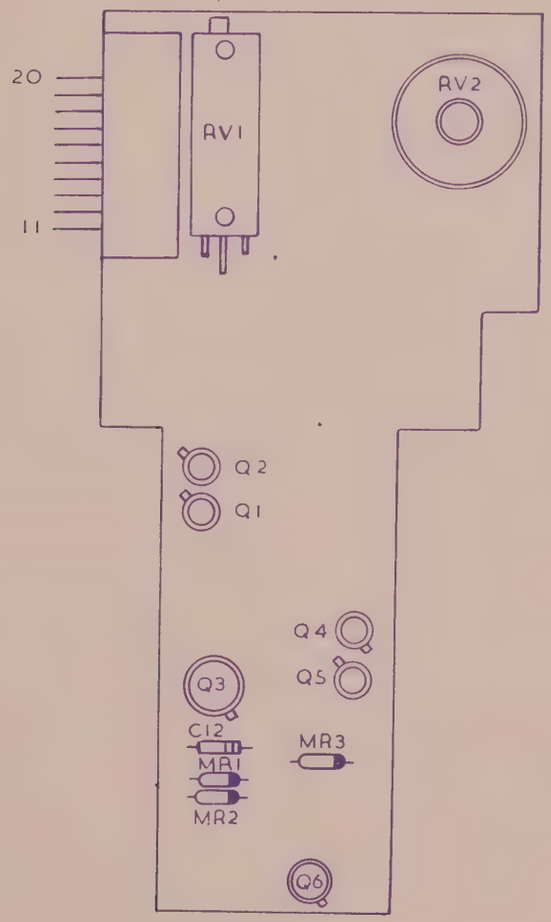

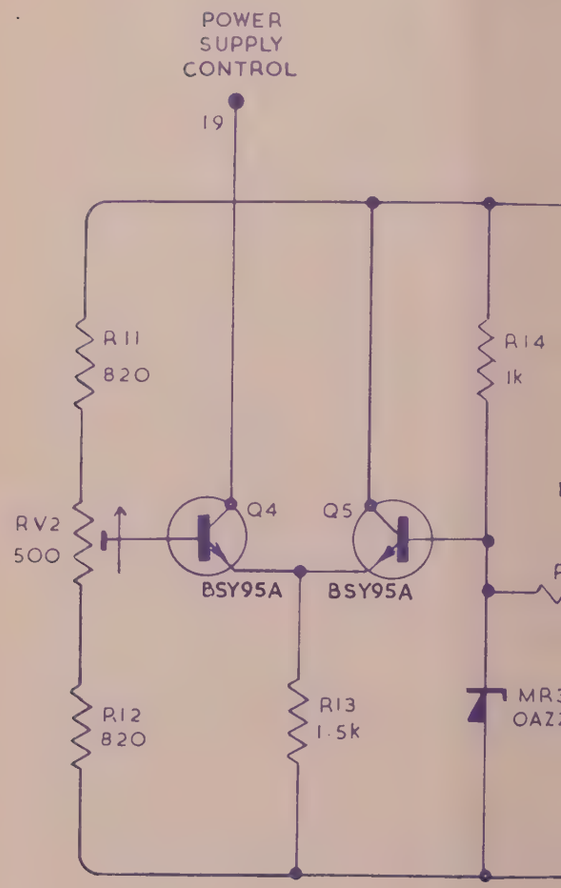

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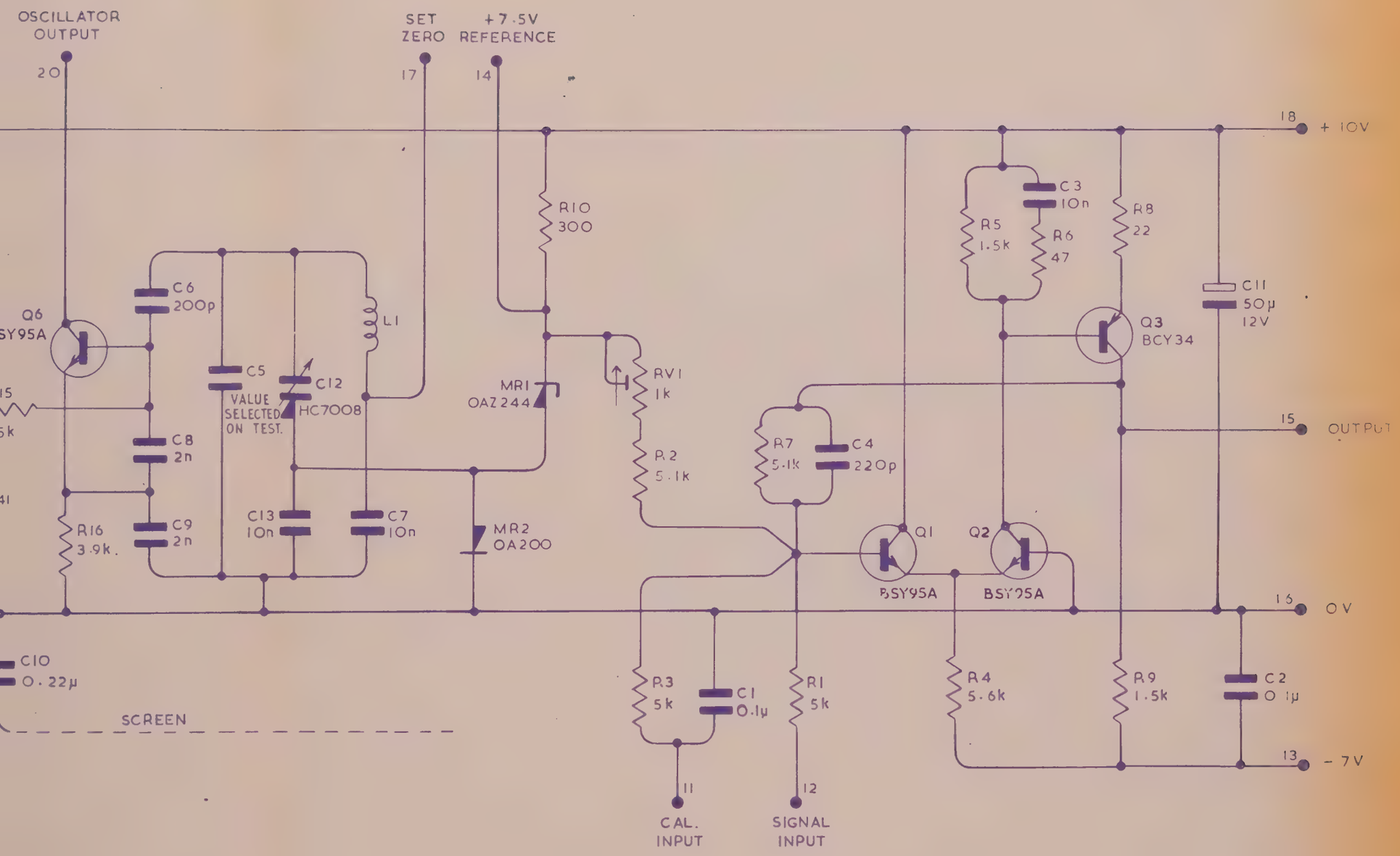
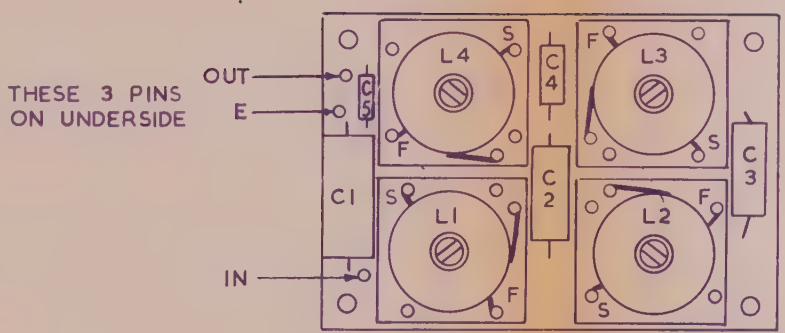


AMPLIFIERS & OSCILLATOR M.4085/



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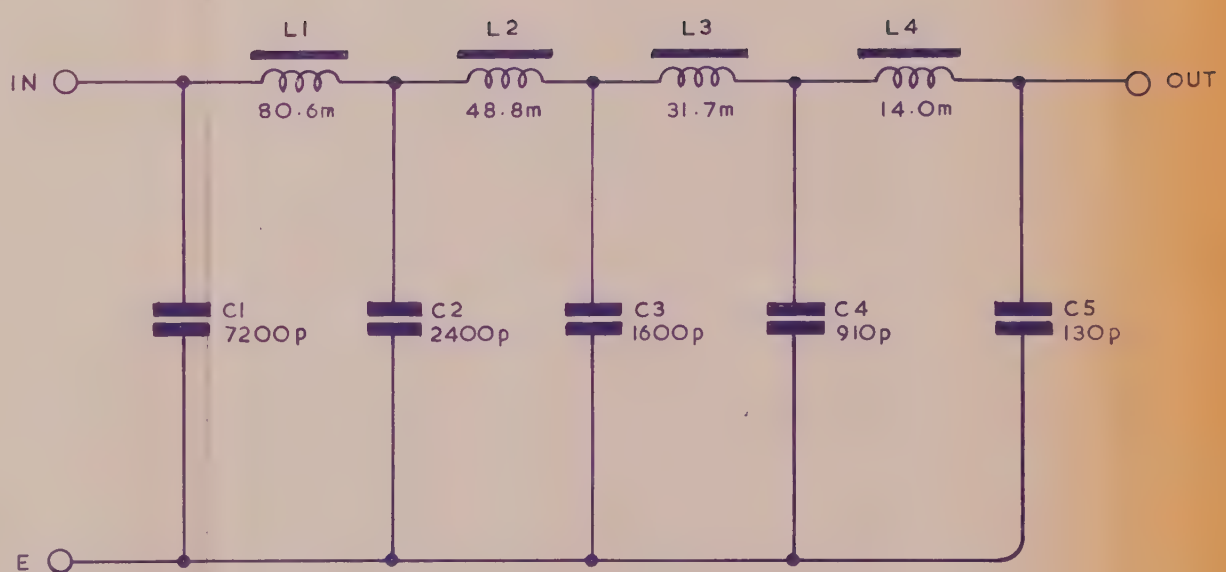
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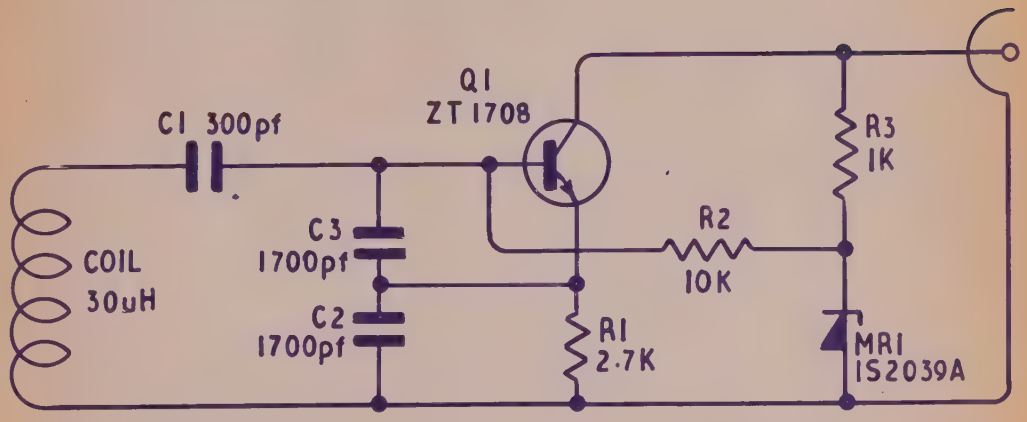
L2
L3
L4
IN
OUT
80·6m
48·8m
31·7m
14·0m
C1
7200p
C2
2400p
C3
1600p
C4
910p
C5
130p
E

AM4100/1

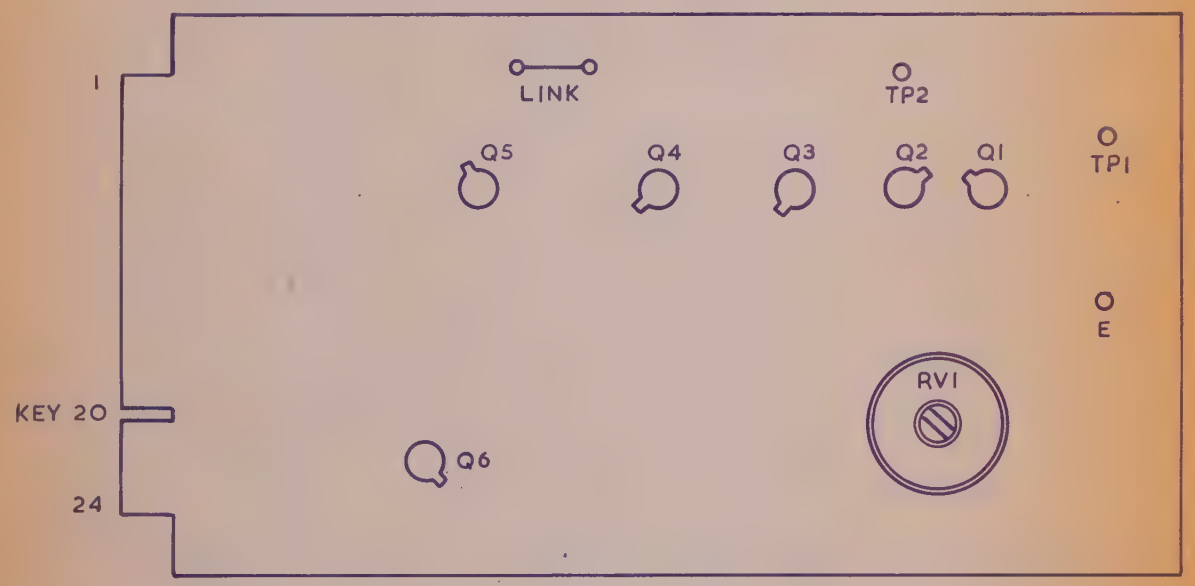
THIRD ANGLE PROJECTION

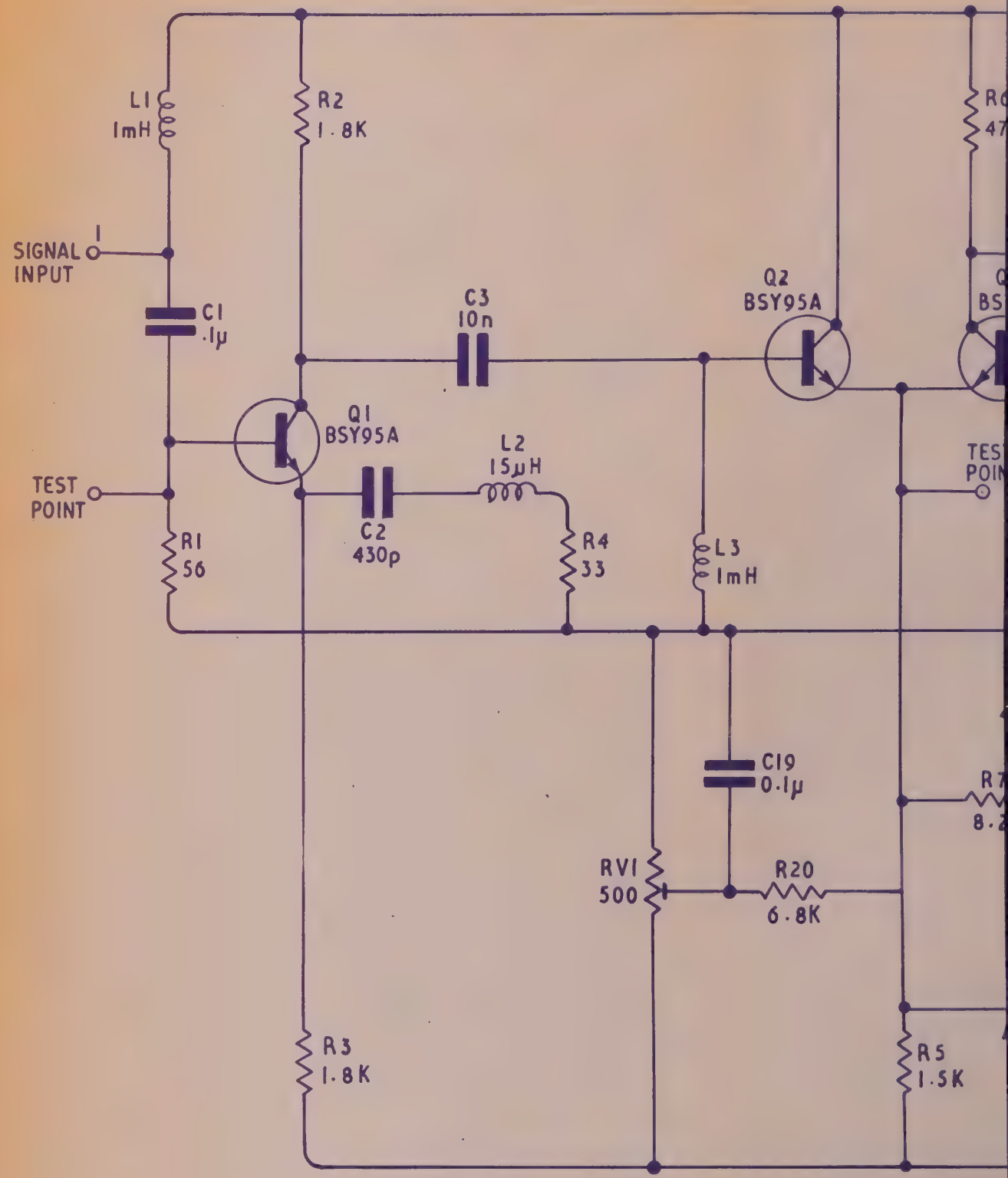
SED ON

00/H
500/L
823

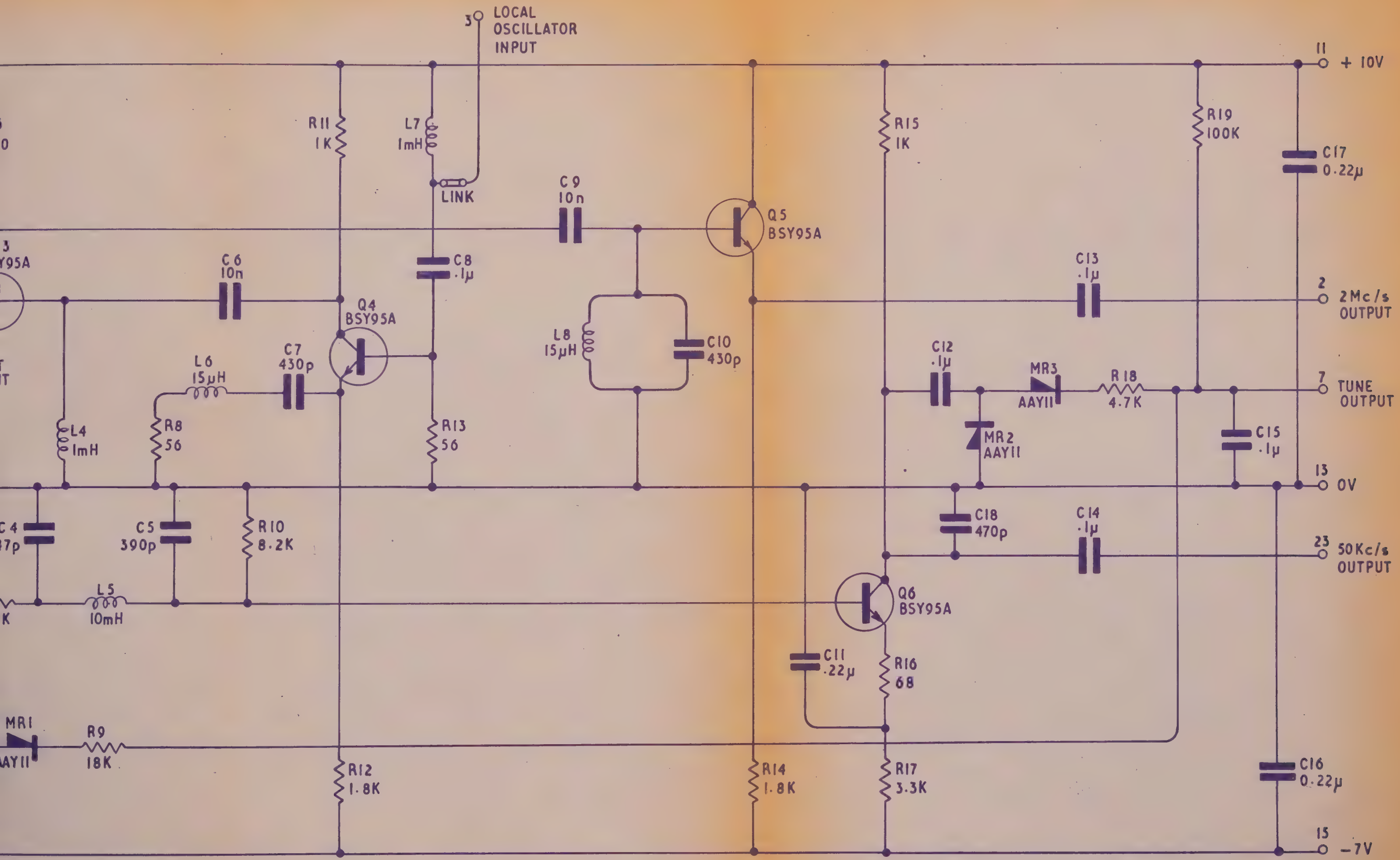


DIMENSIONS ARE THOSE OF THE FINISHED PART			GENERAL LIMITS: DECIMALS :	TOOL Nos.:
DIMENSIONS IN INCHES			FRACTIONS :	
SCALE:			OR AS STATED	
			MATL. :	FINISH :
RAWN				
G.L.				
IECKED	1	01/2096	18·6·65.	
	C		30.3.65.	TITLE : OSCILLATOR CIRCUIT.
PPROVED	B	01/2030	24.3.65.	DRAWING NUMBER AM4100/1
	A		19.3.65.	



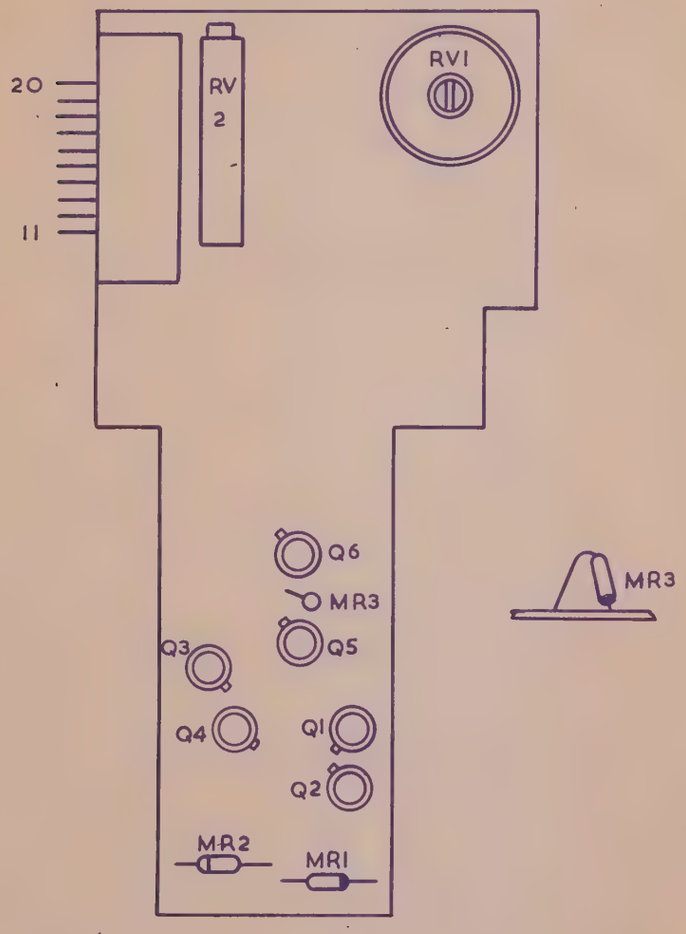


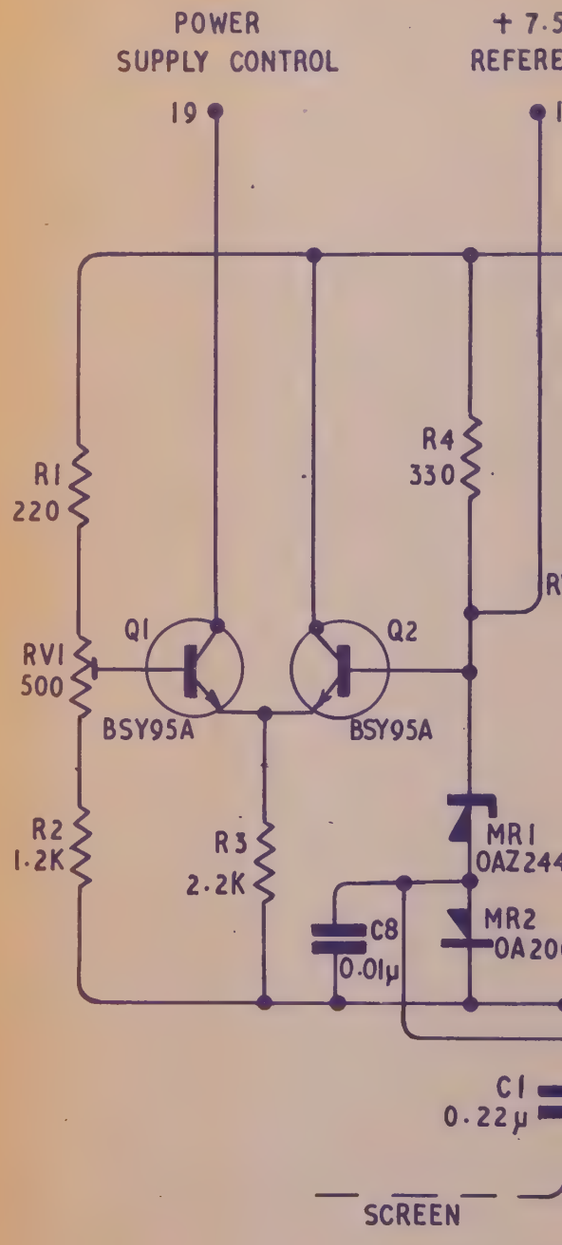
ISSUE No.	D	E	/								SOUTHERN INSTRUMENTS LTD. CAMBERLEY, SURREY, ENGLAND



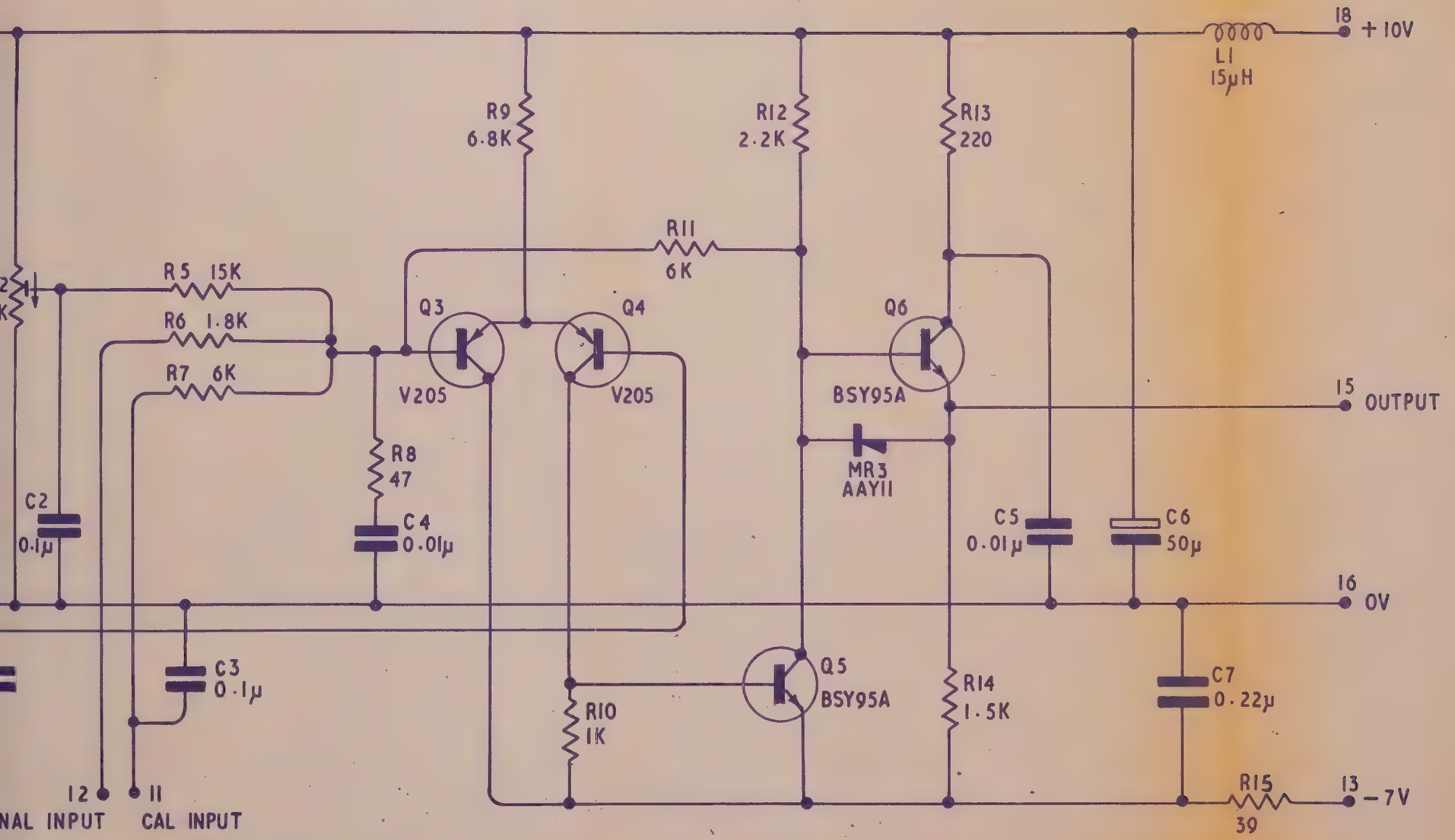
MIXER TYPE 'U'

M4110/1





UE No.	C	D	1	2							SOUTHERN INSTRUMENTS LTD. CAMBERLEY SURREY ENGLAND	



AMPLIFIER | M4111/1

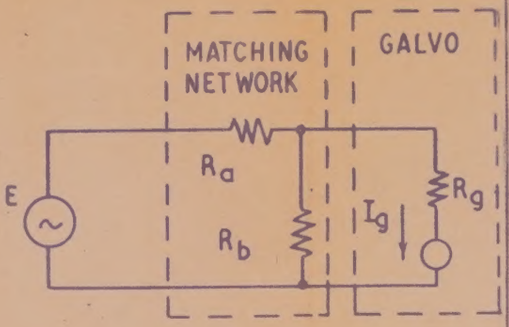
GALVANOMETER MATCHING NETWORKS

When using electromagnetically damped galvanometers, a resistive matching network is normally required. This network simultaneously reduces the input to the correct level and presents the correct matching resistance to the galvanometer.

The appropriate equations are as follows:-

$$R_a = \frac{E}{D} \cdot \frac{1}{K}\left(\frac{R_d}{R_d + R_g}\right) = \frac{E}{D} \cdot K_1$$

$$R_b = \frac{R_a \cdot R_d}{R_a - R_d}$$

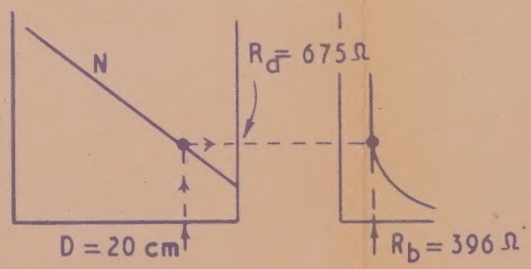


where R_a = series matching resistance (kohms)
R_b = parallel matching resistance (kohms)
R_d = specified damping resistance for galvanometer (kohms)
R_g = galvanometer resistance (kohms)
E = input voltage (volts)
I_g = required galvanometer current (mA)
D = required galvanometer deflection (cm)
K = galvanometer sensitivity (mA/cm)

The quantity $K_1 = \frac{1}{K}\left(\frac{Rd}{Rd+Rg}\right)$ depends only on the galvanometer characteristics, so that a family of curves may be plotted relating R_a to D, for a fixed input voltage - say 1 volt. A family of these curves is plotted on the right, for galvanometers in the range manufactured by S.M.I.Ltd. For voltages greater or less than 1 volt, R_a must be increased or decreased in direct proportion.

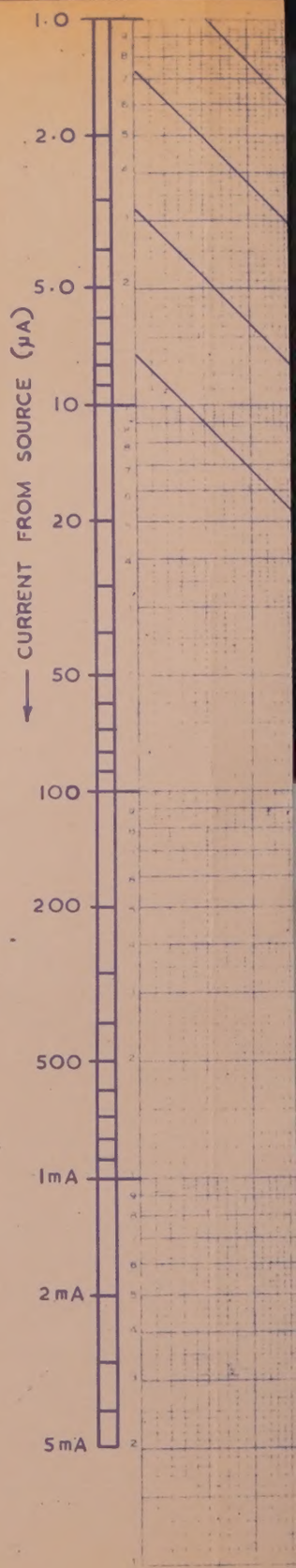
The value of R_b can be found from the extreme right-hand graph, once R_a is known.

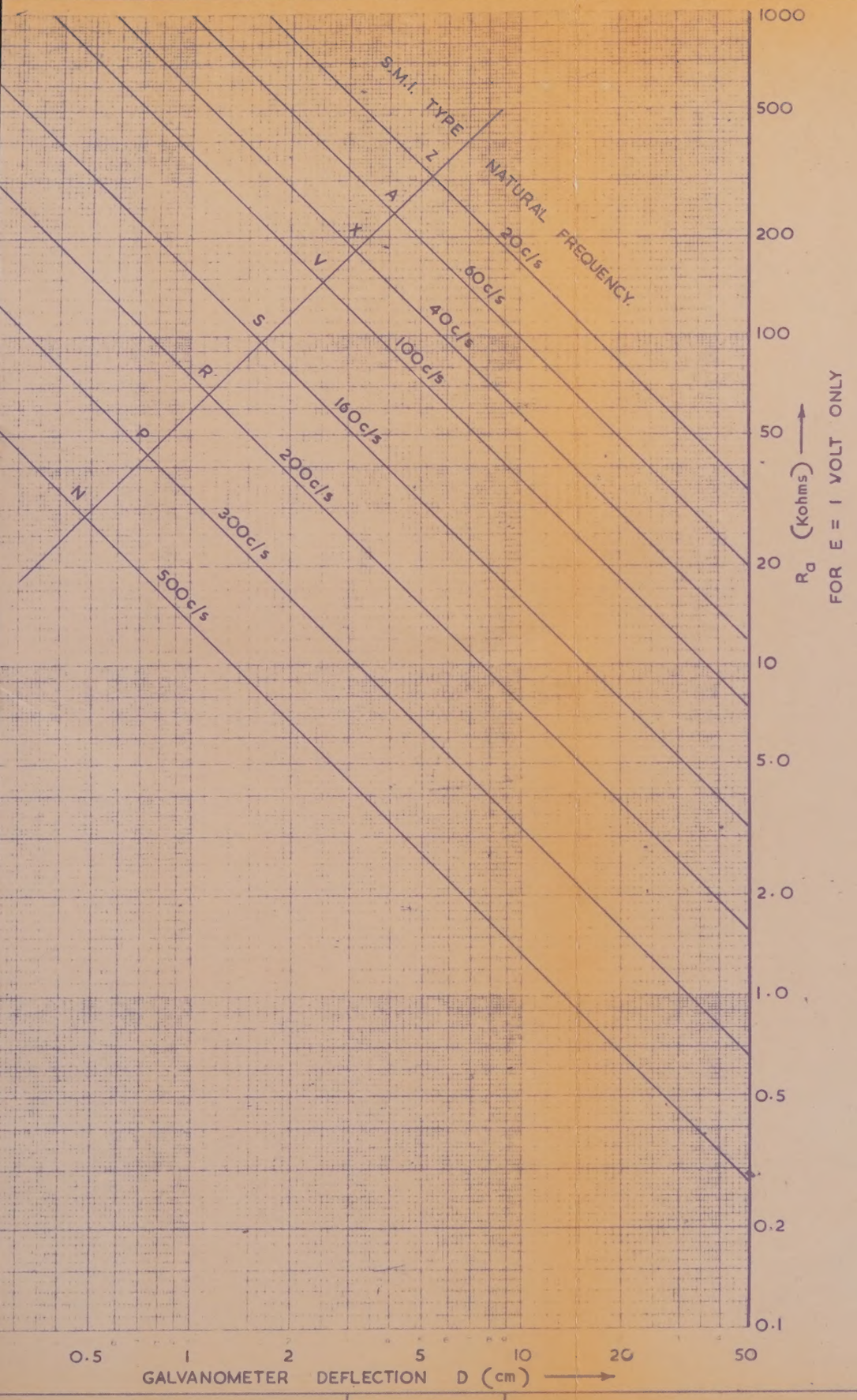
EXAMPLE: for 20 cm deflection of a type N galvanometer, with 1 volt applied, we find R_a = 675 ohm, R_b = 396 ohm.
For 5 V applied, R_a = 5 x 675 = 3.35 kohm, so R_b = 270 ohm.

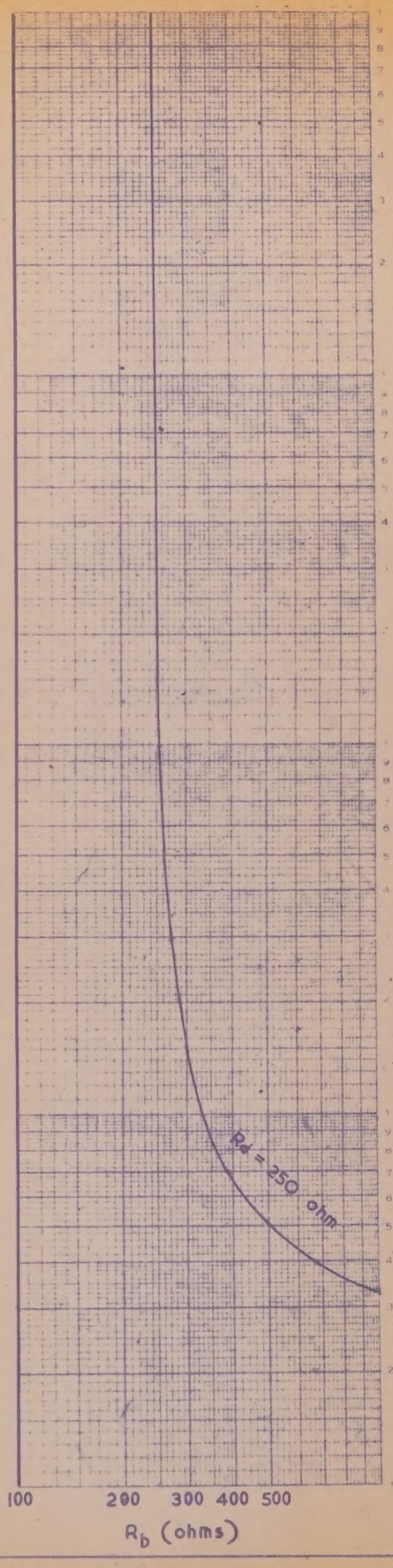


NOTES: 1. If the source of the input voltage E has a finite internal resistance, then the value of R_a should be reduced by this amount.

2. The current drawn from the source for a given value of D can be found approximately from the scale on the l.h. side. This assumes no voltage drop across the galvanometer, so the answer will be too large for values of R_a below about 1 kohm.







S.M.I. GALVANOMETER MATCHING NETWORKS

M.1300/341

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